Economic and Social Commission for Asia and the Pacific

Water Resources Journal

E/ESCAP/SER.C/127

December 1980 (Quarterly)

United Nations

Contents

	Page
Water and sewage treatment practice: Current strategies in water treatment developments worldwide	1
Third World tests for sand filters	8
Emergency care in natural disasters: Views of an international seminar	14
Water technology: Viruses in drinking water	19
Significant meteorological events in the ESCAP region in 1979	26
Water: a perspective on global issues and politics	30
Selective information section	42

The designations used and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The views and opinions expressed are the authors' own and do not necessarily reflect those of the United Nations Secretariat. Mention of any firm or licensed process does not imply endorsement by the United Nations.

WATER AND SEWAGE TREATMENT PRACTICE: CURRENT STRATEGIES IN WATER TREATMENT DEVELOPMENTS WORLDWIDE*

Introduction

Water treatment development strategy in the United Kingdom differs in many respects from the strategy adopted in the developing countries. In many of the latter countries, water demand greatly exceeds supplies available; as a result the main search is for simple robust least-cost solutions to the treatment of large quantities of raw water. For example, the city of Bombay is currently constructing one of the largest treatment works to be built in one phase to treat 1.9 million m^3/day.

In addition, treatment strategy in developing countries reflects two principal characteristics relating to the nature of the water to be treated. First, in the tropical and sub-tropical developing countries where rainfall is adequate to plentiful, the main sources of water in large quantities are the rivers which may have very high suspended solids at times. Secondly, in the developing areas of the Middle East where a desert climate prevails, it is becoming necessary to use desalinated sea water or high temperature underground waters with a high mineral content, with little or no other water available for blending.

In the United Kingdom, the current strategy is principally concerned with the achievement of fringe economies related to the use of closer methods of control of water treatment processes, and finding means of solving pollution problems arising from the use of industrially-polluted sources. There have been no signs of major changes in strategy during the past 30 years; but there has been a substantial increase in knowledge concerning the possible significance of various organic and inorganic compounds in water, and this is leading to some reappraisal of current treatment methods which it is felt may not be entirely adequate.

What is occurring at present in water treatment strategy is therefore principally the development of well-known techniques for economic reasons, coupled with an investigation into the significance and efficiency of treatment processes in the light of new knowledge concerning water borne compounds and the need to use unusual sources of water. These matters will be illustrated by making reference to examples in relation to typical water treatment processes.

1. Clarification and pretreatment strategy

(a) *Countries other than the United Kingdom*

A characteristic of many rivers in the world is that they contain high levels of suspended solids, particularly after heavy rainfall. The Tigris at Baghdad, Iraq, for instance, regularly contains up to 10,000 mg/l suspended solids with peaks of occasionally five times this amount. Some rivers experience such conditions for only a few days of the year; in others the high suspended solids condition may last for months.

River regulation can cause fundamental changes in the characteristics of such waters. The quality of the Nile River water in the delta of Lower Egypt has altered dramatically since the construction of the Aswan High Dam. Previously it normally contained large amounts of suspended solids which were relatively easily settled in treatment works which included circular sedimentation tanks equipped with botton scrapers for sludge removal. Since the dam has been constructed, the Nile water below it has contained less solids, the flow of water has been more sluggish and it has contained more nutrients. As a result the water is more difficult to clarify and severe algae problems are being experienced at some treatment plants in the delta.

When heavy solids loading of a raw water occurs, the principal aim is to reduce the load economically to such a level as will permit the treatment plant, and particularly its sedimentation stage, to continue to function without severe reduction of output. Whilst the nature of the suspended solids is an important factor, as a rough guide it can be taken that the solids must be reduced to about 2000 mg/l before a sedimentation tank without positive means of scraping can successfully operate continuously at its rated output. It is not always easy to achieve this reduction by any form of pre-settling, especially if the solids are colloidal in nature.

At Maseru in Lesotho the solids in the river are of such a fine colloidal nature that plain pre-settlement reduces the loading by only 50 per cent after eight hours and 60 per cent after 24 hours. With such a water, which can contain up to 10,000 mg/l suspended solids at times, the water delivered to the treatment works may still contain a high level of solids even after pre-settlement, so that recourse may have to be made to two-stage chemical treatment. This has been found necessary at Lima in Peru, and is an expensive measure, but no other obvious solution appears to be available. On the other hand it is not always the case that waters with high suspended solids are difficult to treat; often they will clarify easily given the correct chemical treat-

---

* By F.W. Crowley, OBE, and A.C. Twort, Binnie and Partners, London. Reprinted with special permission from *Water Services*, vol. 84, No. 1008 (February 1980), pp. 95-102.

ment. Even so, with suspended solids in excess of 2000 mg/l, problems of silt and sludge disposal may be large.

Horizontal flow sedimentation tanks are unusually well suited to the treatment of waters carrying a high level of solids. Such tanks can be rectangular or circular in plan, but all should contain a flocculation zone for the addition of chemicals, even if chemical precipitation is not always needed. Because of their large volume, these tanks can often give good results despite maloperation or inadequate chemical dosing. They must, however, be regularly cleaned out; this measure alone is frequently sufficient to permit them to give good results. Horizontal flow tanks are also easy to experiment with, should the characteristics of the water change, or a greater throughput may be added to reduce outlet velocity; a horizontal tray may be added to give greater surface area for settlement; or lamella plates may be added to improve settlement characteristics. This latter modification has been adopted at a treatment plant operated by the city of Penang, using a simple timber construction; and it has resulted in a two-fold increase of output.

Where a water is low in turbidity and suspended solids, with a deficiency or an excess of alkalinity, it may be very difficult to clarify. For these waters suspended solids sludge blanket, sludge recirculation, and lamella type sedimentation tanks may be suitable but conditions have to be right. The raw water needs to be of reasonably constant quality so that the chemical control required is not too sophisticated for local labour skills to cope with, and the range of chemicals needed to make the tanks function as the designer intended must be available. For structural economy and to cope with the large outputs required, treatment plant contractors have tended to move away from the small capacity, traditional type of units towards high capacity, flat-bottomed units. It is not unusual in some countries to have individual tanks of a capacity in excess of 90,000 m^3/day throughput.

Algae problems in many countries are on the increase. Despite the efforts made to treat sewage effluents, thereby reducing the organic and faecal material in rivers, the discharge of treated sewage effluent containing phosphorus and nitrogen nutrients can encourage algae growth; additionally, there has been a wider application of fertilizers and these may significantly increase algae nutrients. The biologist may explain the presence of algae blooms and predict future trends with some accuracy; but this is small comfort to the operator faced with the problem of algae blocking his filters.

Prechlorination of the raw water followed by chemical coagulation may be able to reduce the total algal count by 60 per cent or more but frequently it is the remaining algae population which causes most trouble, particularly in the filters. Controlled chemical dosing with copper sulphate at the inlet to a works may assist by killing algae and to make them more easy to remove in the coagulation stage. A layer of anthracite on the filters will usually help, and can even double or triple the length of filter run in adverse conditions, but the introduction of anthracite to an existing works usually means extensive plant alteration. Sometimes the algae can be so small they pass through the filters and, when this occurs, a secondary dose of primary coagulant or the use of a polyelectrolyte on to the filters may prove effective.

The application of clarification by flotation is a possibility for algae laden waters, but the previous warning relating to suitability of local conditions applies very much to this technique which requires sensitive and careful chemical control. Pretreatment by rapid gravity roughing filters may provide a partial answer in some cases. Micro-straining can sometimes be of benefit, but pilot plant trials beforehand are advisable.

Bankside storage of a eutrophic river water may exacerbate the problem of algae, causing a riverine algal population to disappear only to be replaced by a different type of algae typical of a stored water.

The Fuwa treatment plant in the Nile delta illustrates problems that occur with algae. The treatment comprises chemical coagulation with alum, sedimentation in circular scraped radial flow tanks, followed by rapid gravity sand filtration. Although prechlorination is practised, filter runs are often reduced to three or four hours when algae is present and the nominal works output of 38,000 m^3/day is reduced by half. Typically the raw water has a pH of about 7.0, colour of 7^o Hazen (filtered), turbidity 18 FTU (Formazin Turbidity Units), suspended solids 50 mg/l and total alkalinity 150 mg/l as $CaCO_3$. In February 1979 the total algal count in the raw water was 22,000 cells/ml. Diatoms were dominant, with large numbers of Cyclotella and Melosira also present, both of which are notorious filter blockers. Green and blue algae were almost absent.

After coagulation with alum the count was reduced by 78 per cent to 4800 cells/ml, but the total rated output of the plant was still reduced by 50 per cent. A month later the total cell count in the raw water declined to 10,500 cells/ml and this was reduced to 5000 cells/ml following coagulation with alum. A further 10 per cent removal was achieved through the filters, but the output of the plant was still reduced by 40 per cent.

An interesting feature was that, in the space of one month between the two samples, minute green algae had become numerically dominant instead of the diatoms. These chlorelloid algae are very small, about 4 microns in diameter, and this accounted for the high percentage passage of about 37 per cent through the filters. Many other works suffer occasional algae problems. At both the Upper Peirce works of Singapore

and the Sha Tin works of Hong Kong partial relief is obtained with prechlorination and anthracite capping to the sand filters.

(b) *The United Kingdom*

The strategy for clarification and pretreatment of river waters has remained practically unchanged in the United Kingdom over the past 10 years. Although there have been one or two examples of horizontal tank installations, the vast majority of treatment plants with a sedimentation stage make use of some form of sludge blanket clarifier. The United Kingdom has not yet followed practises in continental Europe, where many examples can be seen of purpose-built lamella tanks, some of which produce startling results in terms of high flow rates and sludge concentration.

The flotation technique of clarification continues to create interest, particularly for the clarification of waters with low turbidity and suspended solids but which may have high colour and high algal population. Treatment plant manufacturers of flotation equipment claim that rise rates in excess of 10 m/h are possible and the sludge produced from the clarifiers is more concentrated than sludge blanket clarifiers. The plants are easy to start up when required, and there are now several prototype installations in the United Kingdom.

Some interesting experimental work was done in 1977 and 1978 on water from Lough Neagh at the Dunore Point treatment plant in Northern Ireland. The existing treatment plant was constructed in 1971 following trials on the eutrophic Lough water with the alternatives of chemical coagulation, microstraining, and roughing filters.

Rapid gravity roughing filters were eventually selected as the preferred method of treatment, and the essential parts of the 136,000 m^3/day treatment plant consist of 18 rapid gravity roughing filters, followed by 18 slow sand filters. During the past 10 years the raw water from the Lough has regularly contained algae populations of 25,000 cells/ml sometimes rising to 40,000 cells/ml. A 30-day operation of the roughing filters recorded in March 1977 showed the average filter runs were less than 24 hours for 75 per cent of the period, less than 12 hours for 31 per cent and less than eight hours for 5 per cent of the period. The slow sand filters operating at about 0.18 m/h generally ran without cleansing for about 100 days but this interval could drop sharply during the spring algal bloom, and occasionally a filter was cleaned after 20 days.

A typical analysis of raw water gave results of 8.0 to 9.0 for pH, 5^o to 25^o Hazen (filtered) colour, turbidity 2.5 to 6.6 FTU, suspended solids 6 to 9 mg/l and a total alkalinity as $CaCO_3$ of 82 to 96 mg/l. Most of the turbidity and suspended solids content was due to algae. On average some 60 per cent of the algae was removed through the roughing filters with a maximum of 75 per cent; and about 60 per cent of the balance was removed through the slow sand filters, with a peak also of 75 per cent.

In one particular test filamentous blue-green algae were dominant whilst in another test the species *Chlorella pirenoidosa* numbered 31,000 cells/ml in a total count of 42,000 cells/ml. In broad terms the results obtained for percentage algae removal were similar to the results achieved at the Fuwa treatment plant in Egypt, with chemical coagulation followed by rapid gravity filters.

To compare the results obtained using roughing filters at Dunore Point with other methods of treatment, laboratory tests were performed in 1977-1978 on the same water containing 42,000 cells/ml algae. Coagulation and sedimentation gave 51 per cent removal; flotation preceded by chemical flocculation (including the use of a polyelectrolyte) gave 70 per cent removal; and flotation without any chemical treatment gave 67 per cent removal. It is not suggested that these same percentage removal rates would apply to all eutrophic waters. The figures are given to illustrate the variable removal rates which are obtained with differing types of treatment, and which are probably mainly related to the dominant species of algae present in the raw water at a particular time.

Prechlorination continues to be widely used for pretreatment, particularly for polluted river sources or where algae is prevalent. But because some of the byproducts of disinfection have been identified as potentially toxic or carcinogenic, this method of disinfection is tending to lose favour. However there seems to be no completely effective and economic alternative, so that there has been no major change to use of another type of disinfectant.

It is fortunate that conventional chemical coagulation and sedimentation processes, particularly when combined with the use of carbon, have been shown to remove to low levels detergents, phenols, polyaromatic hydrocarbons and pesticides. However, there has been a vast amount of research work into the detection, identification and removal of trace amounts of many chemicals in water which may be significant in relation to health. The list of substances that may be potentially harmful grows larger and larger, but the seriousness of most of these substances has yet to be defined by toxicologists, emphasising the need to continue to exploit the least contaminated sources of water first.

One side-effect of the more stringent standards being applied to water quality is the range of sophisticated laboratory equipment which is now almost standard in laboratories for the routine examination of waters. In a relatively short time span laboratories which formerly carried out a limited range of physical and chemical determinations are now often called upon to undertake extra analyses for rare metals and organic

compounds derived from pesticides, herbicides and other sources.

The provision of bankside storage of raw water as a protection against accidental pollution has long been recognized as an obvious safeguard for a water treatment plant drawing direct from a river. Retention can benefit the biological condition of the water, and some improvements will occur to physical and chemical characteristics, making treatment generally easier. More recently, researchers into the transmission of viruses by water have confirmed the benefits of natural virus inactivation obtained by providing raw water storage. But the volume of storage required for this purpose is large.

Whereas the bankside storage recommended for protection against accidental chemical pollution is about seven days detention, that required to prevent penetration of viruses through a treatment plant may be of the order of 20 days to 75 days depending upon water temperature.

In certain parts of the United Kingdom, and notably in East Anglia, high levels of nitrates occur in some surface and ground waters. The nitrate concentrations are in excess of those permitted by international drinking water standards and, because there exists a proven relationship to methaemoglobinaemia in infants, reduction is deemed essential. Nitrate content is unchanged by normal chemical coagulation or pH correction techniques. Consequently, work is proceeding on the evaluation of a number of alternative methods for its reduction. One such method is to use a high rate fluidized bed operating on the principle of biological denitrification using methanol as the source of carbon. The process requires methanol to be added to the raw water before biological denitrification in a fluidized bed reactor, followed by reaeration of the water. It is possible that two such units, each of 2250 m^3/day capacity may be installed for full-scale trials in the near future.

There is a particular need, especially where a raw water is derived from a polluted surface source, for the installation of monitors to detect and give forewarning of the presence of substances which would penetrate conventional treatment processes. Many organic compounds, particularly those which are biologically non-degradable, are in this category. A problem which arises in the use of continuous monitoring instruments is that, because they are nonspecific, the interpretation of unusual readings is difficult and it becomes necessary to duplicate instruments.

A recent development designed to detect the presence of a chemical pollutant is to measure the electrical impulses arising from the physiological reactions of fish to a sample of the raw water. Progress has also been made towards automatic, continuous quantitative determination of the numbers of live and dead bacteria present in water using the principle of chemiluminescent and bioluminescent reactions.

2. Filtration strategy

(a) Outside the United Kingdom

There has been a tendency in the last decade to construct treatment works for larger outputs, often in excess of 45,000 m^3/day. As a result, much effort has been directed towards obtaining maximum economy in the cost of civil construction and plant. Economy in design can be achieved by making filters as large as possible, decreasing water depth in the filter box, increasing the filtration rate by using dual media, and by eliminating expensive filter controls. But these policies can raise problems of hydraulics, metering, chemical dosing and handling of chemicals, and of filter washing and waste water recovery.

In countries where skilled operation and maintenance is not available, simple manual operation of filter valves is nearly always preferable to automatic operation. However a problem arising as a result of increasing the unit size of a filter is that individual filter valves may then become too large for manual operation, and power-assisted valve operation then becomes necessary. This usually implies the need for filter control panels, with power operation of valves by push button or lever; however this is still several steps away from a fully automatic sequence style of operation.

The Bhandup treatment plant in Bombay, India, has been designed to achieve maximum economy coupled with simplicity of operation. The works are rated for a normal output of 1.9 million m^3/day and will treat a blend of two impounded waters and a river water. The blended waters will be subjected to chemical coagulation and sedimentation treatment at least during the monsoon, followed by rapid gravity filtration in four parallel streams of filters. Each stream has 18 filters arranged in two rows of nine each. During the dry season treatment may be by direct filtration only, either with or without prior coagulation and flocculation. Each of the 75 filters has a media area of 153 m^2 and operates on the variable declining rate principle, with a maximum filtration rate under normal works output of 11.5 m/h and an average rate of 7.2 m/h. The outlet from each filter has a restrictor valve in place of the usual flow-controlling valve. All filters discharge to a common pressure conduit which in turn is connected to a chlorine contact tank.

After disinfection with chlorine and pH correction with caustic soda, the treated water is then pumped through a rising main to a nearby flow balancing reservoir. Flow into the works and flow from the works is matched by means of a valued bleed connexion on the rising main back to the chlorine contact tank. The works will be operated so as to maintain a substantially constant level differential between the common inlet

channel to all 72 filters and the level in the contact tank. Under steady flow conditions an increase in differential will indicate the need to reduce the interval of time between washing the filters; conversely, a reduction in differential will enable the filters to be washed less frequently. A retention wall within the chlorine contact tank ensures that the water level in a filter cannot fall below the top of the media when it is being washed. The filters contain a single graded media of effective size 0.8/0.9 mm and a depth of 95 cm.

Two experimental filters will be charged with a 25 cm layer of anthracite.

Many filter works in Malaysia, constructed in the past by Public Works Department engineers, were equipped with simple controls using the principle of inlet flow splitting, avoiding the use of complicated outlet flow controls and slow start equipment. The arrangement has proved perfectly satisfactory so long as there are about six or more filters so that adequate dilution occurs if a newly washed filter should happen to produce substandard water for a time because of the absence of a slow start control. More recent installations in Malaysia also use the principle of inlet flow splitting with outlet pipework and valving sized to limit the maximum filter flow rate. The filters operate with a rising level in the filter box and, although there is some cost disadvantage because of the need for a deeper filter box, such filters are easy to operate with a rising level in the filter box and, although there is some cost disadvantage because of the need for a deeper filter box, such filters are easy to operate and have few controls which might go wrong.

A small but important factor in work outside the United Kingdom is that as the temperature of the water is frequently high, possibly up to 35°C, its viscosity is lower than in the United Kingdom. Consequently wash rates must be increased to obtain the same degree of expansion or fluidization of the filter media. For every 1°C increase in water temperature, the wash rate needs to be increased by about 2.5 per cent to compensate for the lower viscosity.

Superficially slow sand filters appear to offer an ideal solution for many countries, if unskilled labour is plentiful and land is cheap. They are simple to operate and relatively easy to maintain given a plentiful supply of the right grade of sand. In practice conditions may not always be propitious for their use. Too frequently attempts have been made to use slow sand filters on river waters which are too high in turbidity and suspended solids. Even when preceded by settling basins there is no guarantee that the turbidity and solids for some colloidal waters can be reduced to a tolerable level for slow sand filters.

In Lyallpur in Pakistan, for example, one small treatment plant of 8000 m^3/day capacity constructed some years ago is supplied with water from a canal which is first allowed to settle in a retention basin for about 20 days before it passes to one stream of slow sand filters and a parallel stream of rapid gravity filters.

Storage greatly reduces the suspended solids and turbidity, but even so the two streams frequently have to accept water at the works inlet with turbidity up to 100 FTU and suspended solids of 200 mg/l. These concentrations are substantially too high for satisfactory operation of the slow sand filters. Alum is also not always available for the stream with the rapid gravity filters and this may be the reason why slow sand filters were selected in the first place.

For about three months the effluent from the slow sand filters averaged 44 FTU turbidity and 75 mg/l suspended solids; and from the rapid gravity filters it averaged 14 FTU and 29 mg/l which included periods without alum coagulation.

A design of rapid gravity filter which has stood the test of time in treating River Nile water consists of an open circular steel shell containing the media, over which is suspended a rotary raking mechanism. When a filter is washed the arms of the raking mechanism are dragged through the sand bed, simultaneously with the application of the filter backwash. The plant is robust and easy to operate, and the Egyptian water authorities are making use of an updated version constructed by a local firm of shipbuilders.

(b) *In the United Kingdom*

No major changes in filtration practice have been apparent in the United Kingdom over the past two decades. Changes which have occurred do not usually amount to more than a modification or improvement of filtration technology already existing. Most designers of rapid gravity and pressure filters continue to use all-sand media filters overlying plastic nozzles built into a concrete slab floor or fitted on to lateral pipes, instead of sand media overlying graded pebble beds. The latter type of design was often less troublesome than the all-sand filters, but was withdrawn because of the high cost of obtaining suitable pebbles. Filtration downflow rates remain in the range 4.6 to 12 m/l although, in special applications such as oceanaria, rates of up to 36 m/h have been used.

Whenever possible a single media filter design should allow for the application of higher air and wash rates to enable conversion to dual media filters to take place later if required. No effective substitute has yet been found for sand, and the United Kingdom has not emulated the widespread practice in parts of the United States of America and some continental countries of using activated carbon for both filtration and organic removal in the same filter.

Although not a new technique there are not many examples of a secondary dose of coagulant and polyelectrolyte being applied to rapid gravity filters in order to prevent turbidity slip to the filter effluent. At the Three Valleys treatment works during the drought of 1976 there was a marked increase in turbidity which was eventually identified as being caused by small green algae, dominated by a minute species Nannochloris, and Ankistrodesmus, with cell diameters 4 to 8 microns. Records showed that when the settled water effluent exceeded 1.5 FTU because of carryover of algae, the turbidity of the filter effluent increased beyond 0.4 FTU, causing problems in the distribution system. By omitting the secondary dose of activated carbon power which was normally applied before the filters and in its place adding a secondary dose of aluminium sulphate at about 5 mg/l plus a secondary dose of polyelectrolyte at about 0.01 to 0.02 mg/l before the filters, the minute algae were arrested.

3. Strategy for use of highly mineralized waters

In many countries, one of the most neglected aspects of desalination, especially by distillation, concerns the treatment of the product water. Water leaving a distillation plant will normally have a conductivity less than 10 microhm/cm at 20°C, pH between 6.0 and 7.0, total alkalinity (as $CaCO_3$) less than 2.0 mg/l and chlorides also less than 2.0 mg/l. Such a water is flat tasting, unpalatable, aggressive to concrete and asbestos cement, and corrosive to pipes, valves, tanks and nearly all metal surfaces.

Blending with a supply of brackish underground water in predetermined quantities will remedy some of the chemical imbalance reducing the amount of further chemical corrective treatment required, but a ready supply of brackish water is not always available. Unfortunately, blending with a small amount of sea water with total dissolved solids content of 35,000 mg/l or more is not practical, as a blend proportion which correctly adjusts one parameter such as bicarbonate alkalinity will not satisfy the quality requirements for other parameters. Chemical treatment is therefore the only satisfactory method of treatment where blending with a brackish supply is not possible.

The aim of the treatment is to add chemicals to the product water sufficient to produce a thin coating of calcium carbonate on otherwise corrodible surfaces in contact with water, at the same time achieving a stable and palatable water. Control of the chemical application is important; if the pH of the treated water is significantly greater than the equilibrium pH value (pHs), precipitation of calcium carbonate then takes place too rapidly, producing chalk.

Chemical treatment to increase the alkalinity of the water also achieves improved palatability. In both cases, however, the effect of any residual chlorination required to protect the distribution system must be taken into account. Failure to treat the product water can lead to severe problems in the distribution system and there are instances of internal plumbing systems to houses having to be replaced in less than two years where conditioning has been inadequate.

There are a number of methods in use for the addition of chemicals to increase the alkalinity of product water. Each method needs to be evaluated according to availability and cost of chemicals to find the most appropriate one. The method used for the desalting plant at Lok on Pai, Hong Kong was to add carbon dioxide and excess hydrated lime at dosage levels of 44 mg/l and 38 mg/l respectively. This provides a satisfactory pH value of about 8.5 with a total calcium bicarbonate and carbonate alkalinity of about 35 mg/l as $CaCO_3$. It assumes a 70 per cent absorption efficiency of carbon dioxide and the use of hydrated lime with 97 per cent $Ca(OH)_2$ content. Treatment by chemicals has been subsequently stopped as the product water is now blended with stored natural waters.

Deep well supplies in many countries are often highly mineralized and may also have a high temperature. Artesian wells in north-western Saudi Arabia, at Sakaka, are frequently 1000 m deep and produce water at 48°C containing up to 0.39 mg/l total iron (as Fe) and 0.22 mg/l manganese.

Whilst the iron and manganese contents are above the World Health Organisation's (WHO) highest desirable levels, they are below WHO maximum permissable levels and might therefore be tolerated for a small supply. But the only economic way in which to cool the water is by use of a forced draught cooling tower; this not only enhances the propensity of the iron and manganese to precipitate, but causes organic pollution of the water from the air. Consequently, treatment of the water has to include: cooling; cascade aeration; rapid gravity filtration using a catalyst for iron and manganese removal; disinfection by chlorine; and possibly the addition of lime or pH correction if necessary.

4. Plant control strategy

Automatic dosing of chemicals in water treatment is now in more widespread use throughout the world. The principal reasons for this are larger sized plants; a wide variety of chemicals to apply; and, the need for closer dosing control to achieve best economy in the use of chemicals. Automation does not necessarily reduce labour problems and costs: it may merely change the type of problem encountered.

The use of sophisticated automatic controls in developing countries or in remote locations may be inappropriate, where adequate skilled servicing is not available, or where there are difficulties in obtaining replacement parts from abroad. On the other hand, some form of mechanical handling of chemicals is desirable.

In developing countries, unemployment may be high and labour cheap, but it does not necessarily follow that the waterworks has the resources to employ many operators. At one waterworks seen, for instance, it is (reasonably) safe to drink the water supplied in the morning but not in the afternoon, because the labourer whose job it is to hump bags of chloride of lime tends to become inactive after midday! 'Simple automation', if that is not a contradiction in terms, and some form of mechanical handling of chemicals is desirable for all treatment plants in order to encourage correct dosing of chemicals.

There is a tendency nowadays, however, to achieve control and proportionate dosing by means of electrical feedback signal systems, but where the climate is very humid, or if the electrical equipment is not robust or is wrongly placed, it may be short-lived. Small defects in such equipment arising from lack of maintenance can give rise to large and erratic errors of output, or total non-functioning and abandonment. There is a need to resuscitate the use of some of the simpler, more robust type of mechanical and hydraulic control equipment which was formerly used in treatment works. Such equipment, if made of the right materials, can give long trouble-free operation with negligible maintenance requirements.

Backwash provisions for rapid gravity filters overseas need special attention where the raw water is of variable quality, containing high suspended solids at times. Reserve quantities of wash-water need to be available to give beds prolonged washes from time to time when dirty water has to be filtered. At the same time, rates of application of backwash (and air scour if used) must be strictly limited, so that disruption of beds or serious loss of media is not possible. In many plants which have reached the stage of requiring complete renewal of filter media, the most prevalent cause has been defective washing of the beds. Once washing is inadequate, progressive deterioration sets in, leading to mud-balling and cracking of beds, overturn of media, failure to filter properly, and sliming of the treated water pipes due to passage of coagulant through the filters.

Where anthracite is used this must be reflected in ever more liberal provisions of washwater and accurate control of rates of flushing. Even with careful control there may be a steady loss of anthracite of up to 25 mm per annum from the bed. Reserves of anthracite need to be stockpiled for replenishment of beds. The greater freeboard necessary to contain the anthracite when backwashing may mean that measures have to be considered to modify a filter design which uses surface flush.

Modern control technology can be used successfully wherever conditions are appropriate, and substantial benefits in economic use of chemicals can thereby be achieved. At the Layong treatment works in Brunei, rated for 27,000 m^3/day output, the raw water is acidic with little natural alkalinity, with colour normally between 40 and 150° Hazen units. But at times the colour can rapidly increase to about 500 units under flood conditions. The water is sensitive to treat, not unlike peat waters of the United Kingdom. Chemical treatment of the water is by the addition of lime followed by alum coagulation, aeration, sedimentation in horizontal flow tanks, and rapid gravity filtration. To prevent excessive amounts of soluble aluminium passing to the filters it is necessary to adjust the pH for the coagulation process in the range 6.0 ± 0.2.

This very tight control is achieved by installing pH monitoring systems for the raw water, dosed water, filtered water, and final water together with conductivity and turbidity measurement of the filtered water. Electrodes are connected by cable to the display panel, in addition to local indication. A sampling pump system was not chosen because such a system gives too much inertia. Improved reliability is obtained by fitting two electrodes in each position, transmitting the mean value to the console and using an error detection circuit with alarms to indicate excessive differentials.

The foregoing equipment has now been working for two years and it is believed that its cost has already been recovered many times over by the savings in chemicals. The main problem with such a system is to ensure that the electrodes are regularly kept clean.

At the Sha Tin treatment works in Hong Kong, capacity 910,000 m^3/day, all chemicals used in the treatment process are applied at rates proportional to works flow. In the case of alum, stock solutions are prepared by density control with automatic batching and changeover of solution tanks. The 42 filters are all washed automatically against loss of head or time with an inbuilt system for queuing and alternative manual initiation of the washing sequence. A similar degree of automation has also been provided at the Upper Pierce treatment works in Singapore which has a capacity of 13,000 m^3/day.

The type of equipment used in Brunei, Hong Kong and Singapore requires regular attention and servicing but where the skills are available and can be paid for, there is no reason why this level of technology should not be used in developing countries.

Acknowledgement

This paper is reproduced with the kind permission of the Institution of Civil Engineers (ICE) and was originally presented at the symposium, Water Resources – a Changing Strategy, organized by the ICE from 2-5 October 1979. The paper will be included in the conference volume due to be published in mid-1980 which will also include relevant discussion points.

THIRD WORLD TESTS FOR SAND FILTERS*

A. Background information

Slow sand filtration is seen as a means for achieving some of the goals set out by the World Health Organization's International Drinking Water Supply and Sanitation Decade (1981-1990). The specific objective of Phase 1 of the sand filtration programme was to develop appropriate criteria for the design, construction, operation and maintenance of filtration projects under local conditions in the countries concerned.

The pilot plant studies, carried out at five institutes discussed in Section E, covered topics directly related to either the performance of the process or the cost of the system. The main topics in the programme were:

(a) Performance of filters under tropical conditions and, in relation to raw water quality especially, turbidity, bacterial pollution etc.;

(b) Alternative modes of operation for small filter plants;

(c) Effects of different types of specifications of filter material;

(d) Effects of higher filtration rates;

(e) Influence of shading on the filters;

(f) Simple pretreatment methods for turbidity reduction prior to filtration.

Each institute built a least three pilot filters – each approximately 1.5 m in diameter and at least 2.5 m deep and provided with filter regulation, control and measuring devices. One filter from each set was used as a control.

Though the filters' biological processes necessitate operation being as continuous as possible, small supply systems in developing countries often operate for a part of the day only. Studies at the National Environmental Engineering Research Institute (NEERI) in India assessed the effect of discontinuous operation on the filters' performance and the practical implications for their design and operation.

Initial studies focused on use of the filters for an 8-to-10-hour day after which both the raw-water inlet and the filtered-water outlet were closed. The full depth of supernatant was left stagnant during the night. Results showed that bacteriological quality of the water tended to deteriorate during the stopping time, particularly in the layer of water in contact with the biologically active upper part of the filter bed.

Operation was therefore modified so that at the end of eight hours the raw-water inlet was closed but the outlet value remained open. Filtration thus continued but at a declining rate, caused by the constantly falling head of the supernatant. Next morning the raw-water supply was resumed. Results indicate that this alternative does not significantly impair filtrate quality and, in addition, the area of filter-bed required is much less than for operation with closed filters. With sufficient initial head of supernatant, stagnant conditions will seldom occur. To prevent accidental drainage of the bed, an overflow weir should be provided in the outlet line.

One difficulty with declining-rate filtration is the limited time to top up the supernatant reservoir in the morning. With gravity flow, this is no serious problem though it must be calculated in the design of any pretreatment unit. If raw-water pumps are used, however, their capacity will need to be raised, in which case it may be cheaper to construct an additional raw-water storage tank which can be filled intermittently and will feed the filters by gravity. Such a tank would, of course, allow water to flow to the filters during the night, thus achieving virtually continuous operation and further increasing production.

1. *Alternative filter materials*

In principle any inert granular material can be used in filters, though in almost all cases sand is preferred. Sand of the right specification – effective size (ES) between 0.15 and 0.30 mm and uniformity coefficient (UC) below 2 – is not always easily available near a projected filtration plant. The Asian Institute of Technology (AIT), therefore, investigated the possibility of using burnt rice husks – a widely available material – as a filter medium. NEERI, meanwhile, experimented with filter-beds of natural sands and subjected to a minimum of grading.

AIT studied three types of filter-bed:

(a) A slow sand/burnt-rice-husk filter and its ability to function in combination with a coconut fibre filter (series filtration system);

(b) A dual-media filter (coconut-fibre upper layer and rice-husk lower layer in the same box); and

---

* By Paul Kerkhoven of the International Reference Centre for Community Water Supply of the World Health Organization. Reprinted with permission from *World Water*, vol. 2, No. 9 (September 1979), pp. 19-30.

(c) Dual media filters (rice husks or coconut fibre overlying sand).

Generally the rice husks gave good results for very small filters (household), but their low mechanical strength made them unsuitable for full-scale filters. Full results are described in the project reports.

Careful grading of natural sand to meet very strict specification is costly, so NEERI appraised the performance of filters with so-called builder-grade sand – river sand which has had a minimum of screening. Medium (ES 0.25 mm and UC 2.92) and coarse (ES 0.32 mm and UC 2.59) builder-grade sands were tested and compared with normal graded fine sand (ES 0.21 mm and UC 2.10).

Bacteriological checks showed that, with graded fine and builder-grade medium sand, more than 89 per cent of filtered water samples were free from *E coli*. With coarse builder-grade sand, however, the proportion sank to only 66 per cent. Statistical analysis of bacteriological data revealed that graded fine and builder-grade medium sands were equally efficient in removing *E coli*.

As expected, builder-grade sands gave longer runs than graded fine sand. In order of increasing grain size, the average length of run at 0.1 m/h filtration rate was 28, 35 and 38 days respectively. Depth of penetration of impurities, however, also increased with grain size, illustrated by greater numbers of phytoplankton in the lower sand layers. This implies that, where coarser sand is used, a deeper layer (about 3 cm) needs to be scraped from the top sand during filter cleaning. However, satisfactory performance and economy in construction and maintenance was obtained from builder-grade sand with ES up to 0.3 mm and UC below 3.

2. *Higher rates of filtration*

Most of the participating institutions studied filtration rates higher than the traditional 0.1 m/h. Their findings indicate that rates of 0.2 and 0.3 m/h are possible where raw water turbidity is low, without significant deterioration of filtrate quality.

Higher rates of course decrease filter-run times. In the NEERI studies, the average length of run for filters operated at 0.1, 0.2 and 0.3 m/h was 45, 26 and 13 days respectively. Assuming a downtime of four days per cleaning operation, this gives a corresponding output per annum of 806, 1510 and 2000 m^3/m^2. Thus, the output increases with increased filtration rate, but follows a law of diminishing returns.

3. *Shading of filters*

Although algae sometimes play a positive role in the performance of slow sand filters, their effect can also be detrimental, and generally abundant growth of algae in the supernatant water reservoir should be avoided. However, a high algae content in the supernatant does not necessarily reduce the length of the filter run.

Various species, such as filamentous green algae, remain in suspension during the run and do not clog the filter-bed or influence filter performance. They nevertheless can hamper drainage and scraping, by forming a sticky layer on the sand surface.

As a result of various experiments, it is apparent that shading of filters under tropical conditions should not necessarily be standard practice. In cases where algae are a problem and regular harvesting proves difficult, shading certainly will be useful.

4. *Simple pretreatment systems*

Turbidity and content of colloidal material in raw water can be limiting factors in filter application, but most sources present few problems. Tropical rivers, however, can have very high turbidity during the rainy season and various simple pretreatment systems to cope with this were studied.

The simplest and most appropriate were river bed filtration, storage and plain sedimentation. Other suitable techniques are rapid "roughing" filtration and horizontal-flow coarse-material prefiltration.

River-bed filtration may be used for low turbidities of 10-100 FTU (Formazin Turbidity Units); turbidities up to 200 FTU can be tolerated for short periods. The principle is based on the removal of suspended solids in a bed of granular filter material situated on the river bed.

Storage is required if the average annual turbidity is more than 1000 FTU. Suspended matter is removed by natural settlement and biological processes. Plain sedimentation may be applied for average annual turbidities of 20-100 FTU, though it will work for a few weeks up to 400 FTU.

Rapid "roughing" filtration can be used for turbidities of 20-100 FTU if suitable materials such as coconut fibre or coarse gravel are easily obtained. These materials function as the medium in a filter box similar to the slow sand filter.

Horizontal-flow coarse-material prefiltration can be used up to 150 FTU with coarse gravel or crushed stone as media, with a filter box similar to that for sedimentation.

B. Field experience

To obtain more information on the performance of slow sand filters already in operation, the participating institutions each launched a two-pronged investigation in their own countries. They first assembled an inventory of number, type, design and present condition, and then undertook more detailed case

studies on a number of selected plants, rating their performance relative to operation, maintenance and management. In assessing their findings, use has also been made of studies in other developing countries.

At first sight the over-all picture is not all that favourable. Although many schemes are in good condition, in various cases short filter-runs and bacteriological inefficiency were reported. Sometimes raw-water quality was to blame, but in the majority of cases poor performance stemmed from design and construction deficiencies or improper operation and maintenance practices.

1. *Quality of design*

Good design is a prerequisite for good filter performance. Frequently design specifications were found to hamper or even prevent proper operation and maintenance. This was true not only for basic features such as dimensions but also in the absence of provisions for filter regulation and control.

(a) *Size and layout of filter units*

For safe and uninterrupted operation, at least two filters are needed so that when one of a pair of 0.1 m/h filters is being cleaned, the other will not exceed the acceptable rate of 0.2 m/h. In the plants investigated often only one filter was provided.

Where filters are located below ground level, the supernatant water can often become polluted by dirt or sand if the walls of the filter-box are not extended to a reasonable height above ground level.

(b) *Filter-bed and supernatant reservoir*

To avoid disturbing the purification process, the depth of the filter-bed should never drop below 0.6 m. Since the top 10-20 mm will have to be removed regularly during cleaning, a new filter-bed should never be less than 1 m thick, thus avoiding refilling more than once every few years. Investigators often met filters with thinner beds, giving low purification efficiencies and increased maintenance requirements.

Often the supernatant water level too was of insufficient depth, resulting in short filter-runs. A depth of 1m (range 1-1.5 m) for the supernatant water layer is usually suitable for a filter-run of one to two months.

(c) *Inlet structure*

Equal distribution of inlet water over the filter-bed area prevents turbulence and damage to the Schmutzdecke. However, the inlet for small filters is often nothing more than a pipe ending at some distance above the bed and frequently leading to scouring in the medium. Some simple tiles beneath the inlet at the surface of the filter bed may solve this problem.

Another problem is adjustment of the supernatant water level. This can be accomplished with a float-controlled butterfly valve, but these often fall into disrepair and their maintenance is neglected. More appropriate, particularly for small schemes, is a manually operated gate valve in the inlet line, plus a simple overflow provision – a protection often found to be lacking.

The inlet may also be needed to drain the supernatant water for filter cleaning, because of the length of time taken by drainage through the bed. Drainage through the bed in fact often leads to bad practices, such as making openings in the Schmutzdecke, or sucking the water through the bed using a pump on the outlet pipe.

If the raw water inlet is sited just above the bed it can also drain the supernatant water, though when the bed has been scraped several times its level will be lower and less supernatant will drain out. This can be overcome by using an inlet box with removable means below the top of the filter-bed (see figure I).

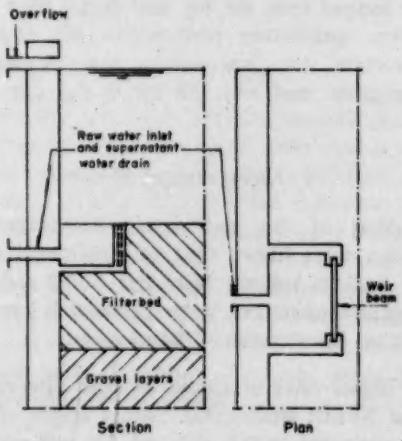

Figure I. Raw water inlet and supernatant water drain with removable weir beams

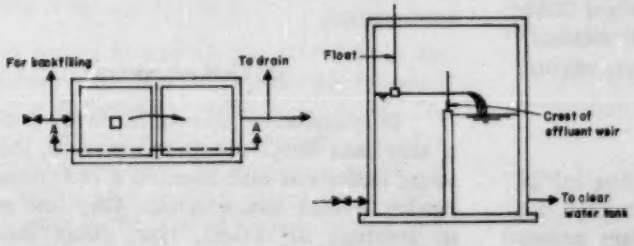

Figure II. Standard outlet weir chamber

(d) *Outlet structure*

One of the most prevalent omissions in outlet structures is a simple overflow weir in the effluent line, with its crest slightly below the top of the sand bed. This guards against negative pressures in the bed, and is also a safety barrier against accidental draining, for instance if the supply is interrupted. A standard outlet weir chamber is illustrated in figure II.

A simple head-loss measuring device is sometimes recommended as a precaution against negative pressures, but this solution is not fool-proof and requires more operator attention.

In many installations visited, the outlet had no means of measuring the flow through the filter-bed. Nevertheless, it is advisable for the operator to be able to determine the rate of filtration, and the effluent weir can be used for this by means of a gauging rod. Accuracy can be increased with a V-notch weir. In larger schemes floating weirs can be used for flow control, but maintenance requirements are higher than for a simple measuring weir.

The outlet structure should also include a means of adjusting the filtration rate, surprisingly often omitted. A manually-operated butterfly valve in the outlet line before the weir is the simplest solution.

Another frequent omission in small plants concerns filter drainage. If an effluent weir is provided or a vertical outlet pipe is used, the filters should be equipped with separate drain pipes. If such provisions are not made, an additional pump is required.

In addition, special provision must be made for disposing of the first effluent of a newly commissioned or scraped filter during the "ripening" period. Lack of such a facility often means other unaffected filters have to be taken out of service temporarily.

Lastly, many schemes investigated did not have a means of refilling a filter with treated water – either from the other filters or the clean water tank – from underneath through the underdrain system. This means refilling with raw water from above, which can lead to air bubbles being carried into the filter bed, causing additional resistance and reducing filter-runs considerably.

C. Quality of construction

Construction deficiencies relate not only to poor construction practices but particularly also to incomplete implementation of the designed scheme. Various studies revealed that, because of insufficient guidance and supervision during construction, filter regulation and control devices are sometimes left out.

Filter material specifications sometimes do not match those laid down in the tender documents. Sand is often too coarse for good bacteriological purification. Frequently too, the sand is not properly cleaned before it is brought into the filters, resulting in poor performance.

A prime deficiency in filter-box construction is failure to roughen the walls sufficiently to prevent raw water from the supernatant passing between the smooth wall and the medium and reaching the underdrain untreated.

Special attention should also be paid to the watertightness of the filter-box and the water mains, particularly considering shrinkage of concrete and masonry, differential settlement, and temperature stresses. It is also important that no dust, dirt, pieces of shuttering etc., are left behind in the filter-box or drainage system. Experience indicates that careful cleaning and disinfecting of the box before placing the media is also easily over-looked.

D. Operation and maintenance

Although operation and maintenance (O and M) is relatively easy, it must be properly performed by a caretaker who has sufficient background knowledge and the necessary skills. Obvious as this may seem, the programme has shown this to be one of the major causes of failure – operators had received insufficient training, sometimes none. A short training course for caretakers including on-the-job training as well as classroom sessions is indispensible.

The caretaker must also have the necessary tools, equipment and spares, and receive sufficient technical, financial and administrative support both from the community and the water supply agency.

O and M faults observed during the survey involved scraping of the filters. Sometimes this was not done often enough – only once or twice a year. In other cases the procedure was incorrect – too thick a layer of sand was removed or, instead of scraping, the filter bed was just dug up for "cleaning". Often the scraped filter did not have time to mature before its effluent was supplied to the clean water tank.

1. *Supervision and routine maintenance*

Sufficient guidance and supervision of caretakers is often lacking. Studies in the Gezira region of Sudan revealed that such supervision, nevertheless, is a condition for good plant performance. It can be achieved by regular visits (twice or three times a year) by a technician to the plants, and should be combined with further training and education of caretakers.

Even where an efficient repair organization exists to respond to repair calls, routine maintenance still needs to be done. This should be carried out at least once a year by a properly trained maintenance team. Apart from thorough cleaning and repair of the filters,

the clear water tank, the engines and pumps, the premises etc., such a team could be involved in resanding the filters.

2. *Community support*

Water supply systems are often handed over to their beneficiaries after the construction phase, and, although back-up for major repairs is still provided by the supply agency, the community then becomes responsible for the daily operation, maintenance and management of the system.

A local organization therefore has to be set up to administer supply, collect revenues, and pay the operator. This implies in turn that the community must accept the supply, must understand its advantages, and must be willing to provide a continued support for O and M.

Experience indicates that communities are generally more willing to participate in O and M if they were involved in the preceding phases starting with the decision to establish the new supply.

Also additional inputs in the field of environmental sanitation education are of importance in this connexion. At many plants investigated, poor O and M was at least partly due to a lack of interest and willingness by the community to support the scheme.

E. Basic elements of a slow sand filter

Slow sand filtration is essentially distinguished from rapid filtration by the thin layer called the Schmutzdecke which forms on the surface of the sand bed and consists of a large variety of biologically very active mico-organisms. These break down organic matter, while a great deal of suspended inorganic matter is retained by straining.

The effectiveness of the purification process depends on many factors such as raw water quality, rate of filtration, grain size of the filter medium, temperature and oxygen content of the water. For normal conditions the average performance of slow sand filters in removing particular impurities can be summarized as follows:

(a) Organic matter – slow sand filters produce a clear effluent, virtually free from organic matter;

(b) Bacteria – between 99 per cent and 99.99 per cent of pathogenic bacteria may be removed; cercariae of schistosoma, cysts and ova are removed to an even higher degree; *E coli* are reduced by 99-99.99 per cent;

(c) Viruses – in a mature slow sand filter, viruses are virtually completely removed;

(d) Colour -- is significantly reduced;

(e) Turbidity – raw water turbidities of 100-200 FTU can be tolerated for a few days only; a turbidity more than 50 FTU is acceptable only for a few weeks; preferably the raw water turbidity should be less than 10 FTU; for a properly designed and operated filter the effluent turbidity will be less than 1 FTU.

Filter construction consists of a box containing a supernatant layer of water, a bed of filter medium, a system of under-drains and a set of filter regulation and control devices. Full details can be found in the IRC's design and construction manual (Technical Paper Series 11). The design is also illustrated in figure III.

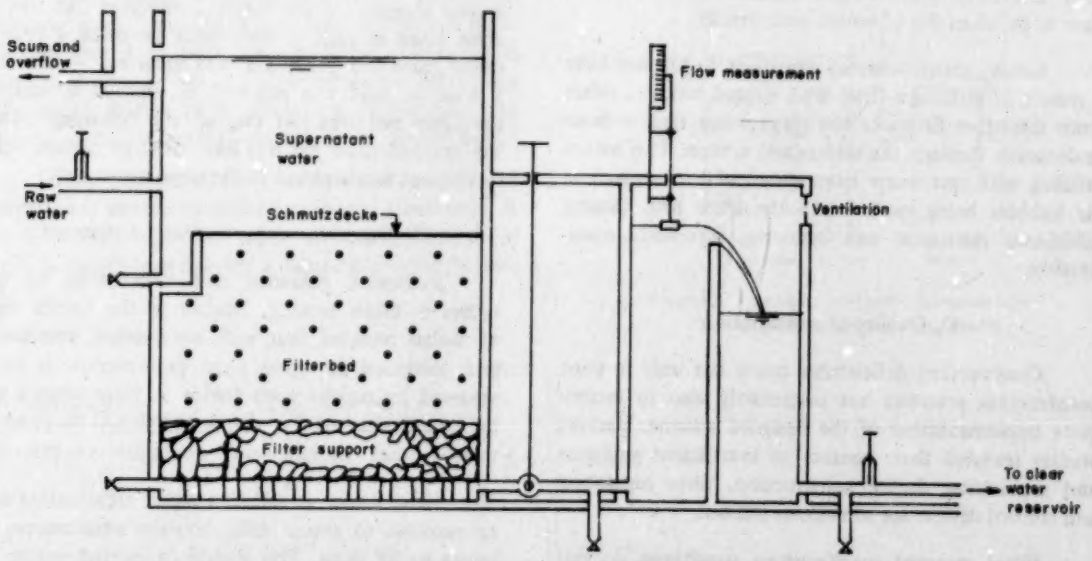

Figure III. Basic elements of a slow sand filter

Phase 1 of the slow sand project involved institutes and agencies in five countries: Ghana, India, Kenya, Sudan and Thailand. These have been joined for Phase 2 by Colombia and Jamaica.

More than 40 organizations have been involved so far – too many to list. But those that worked on Phase 1 research, plus programme co-ordinators for Phase 2 are as follows:

Colombia: Instituto Nacional de Salud, Avenida El Dorado, Carrera 50, Bogota (Phase 2).

Ghana: University of Science and Technology, Faculty of Engineering, Kumasi (Phase 1).

Ghana Water and Sewerage Corporation, P.O. Box M194, Accra (Phases 1 and 2).

India: National Environmental Engineering Research Institute, Nehru Marg, Nagpur (Phases 1 and 2).

Jamaica: National Water Authority, 18 Oxford Road, Kingston 5 (Phase 2).

Kenya: University of Nairobi, Department of Civil Engineering, P.O. Box 30197, Nairobi (Phase 1).

Ministry of Health, P.O. Box 30016, Nairobi (Phase 2).

Sudan: University of Khartoum, P.O. Box 321, Khartoum (Phase 1).

Rural Water Corporation, P.O. Box 381, Khartoum (Phase 2).

Thailand: Asian Institute of Technology, P.O. Box 2754, Bangkok (Phase 1).

Provincial Waterworks Authority, 72 Changwatana Road, Laksi, Bangkhen, Bangkok 21 (Phases 1 and 2).

F. India: updating a long history

In India, purification of municipal water supplies by slow sand filters was introduced more than a century ago when the first installation was made at Palta near Barrackpore, about 21 km from Calcutta, to treat raw water from the Hooghly river. Since then, it has been in continuous use and has proved effective under widely differing circumstances. The Kaval towns of Uttar Pradesh (Kanpur, Agra, Varansai, Allanhabad and Lucknow) have slow sand filter plants fed by river water which has been through pre-sedimentation basins and the lake-fed water supply for the city of Madras is treated by slow sand filtration.

However, despite the fact that slow sand filters have been operating successfully for more than a century, there are still aspects of their performance and operation which are not understood. Engineers also tend to believe that this method of water purification has been superseded by other, more modern techniques.

The advent of chemical coagulation and rapid sand filtration for water of varying quality made the use of slow sand filters for large city water supplies less practical. However, slow sand filtration is often the most appropriate solution for water treatment for small community water supplies drawn from surface sources.

Data on the performance of slow sand filters for small water supply schemes is limited but a common problem seems to be short filter runs due to excessive algal growth or high turbidity during monsoon periods. In the treatment of lake waters, the problem of hydrogen sulphide generation in the filters has been persistent.

Considerable work has been undertaken at the Madras slow sand filter plant to control the problem of hydrogen sulphide. One of the methods tried was to reduce the sand depth to 20 cm but this was not very successful. Pre-chlorination and break-point chlorination were also tried. The latter was found to be very effective and the filters are now fed with pre-chlorinated water and the odour problem is kept under control. However, owing to the reduced depth of sand, the effluent turbidity is not satisfactory.

In the Punjab and Haryana, where groundwater is brackish or contains excessive fluorides, scores of small villages and towns have to depend upon the irrigation canals for their water supply. Under these conditions purification by slow sand filtration provides a simple solution.

EMERGENCY CARE IN NATURAL DISASTERS: VIEWS OF AN INTERNATIONAL SEMINAR*

The past decade has seen considerable expansion in knowledge about the effects of disasters on health and, therefore, of the optimum strategies for the provision of emergency services. The object of the international seminar was to promote the exchange of knowledge and experience concerning the delivery of health services in the wake of such natural disasters as cyclones, earthquakes, floods and drought.

The seminar was organized around five basic principles:

(1) The efficiency of a medical relief operation will be greatly enhanced by advance preparation to meet likely contingencies. This preparation falls into two categories: organizational preparedness, including that of the material requirements of providing medical care; and, physical planning measures, such as the construction and siting of houses and hospitals.

(2) Although in many respects each disaster is unique, the medical problems which will be caused in a specific area by a stated type of disaster are predictable, qualitatively if not quantitatively.

(3) Planning and preparation are paramount in international relief.

(4) Medical preparedness for disaster can be organized to meet probable needs immediately after a disaster; however, it will be necessary to assess the specific effects of the disaster and the health care needs caused by it.

(5) Reconstruction after a disaster provides an opportunity to introduce measures to mitigate a future disaster.

A. The effects of disasters on health

The effects of natural disasters on health can be viewed from two perspectives: the way in which disasters cause injury and death; and disasters as an epidemiological determinant, that is, the way in which disasters may induce ill-health by causing secondary changes in the environment.

In the consideration of disasters as a direct cause of death and injury, the crucial determinant is the type of disaster which has occurred. A clear division exists between the effects of earthquake, and those of other types of disaster, such as volcanic eruptions, floods, cyclones and hurricanes.

Most earthquakes cause death and injury by the sudden collapse of buildings. The number of injuries which occur outnumber deaths by two to three fold. Thus, medical services must be widely and quickly available. The rates of injury and death and the specific population affected are, however, far from random. The number of foreshocks which precede the main destructive shock, the type and siting of housing, and the construction methods employed are among the major influencing factors. Also, age-specific morbidity appears to be greatest in the young and the old (with the possible exception of babies, who if sleeping with a parent will be relatively protected).

The effects of flash flood, other inundations, and high winds present a considerable contrast with those of earthquakes, since deaths by drowning outnumber injuries which result from encounters with floating debris or debris blown around by high winds.

Disasters cause a variety of health problems other than injuries, including the risk of communicable disease, psychological problems, direct environmental risk and food shortage. The belief is widespread that epidemic disease is an inevitable sequel to natural disaster. In reality, however, epidemics have only rarely been observed. The risk of epidemic disease will be increased where people are crowded together without essential services, as in a refugee camp. But even here the risks of transmission of most diseases remain unchanged if adequate water and sewage systems are provided.

Psychological disorders do not appear to be important following disasters. They may fall into two categories. A "post-disaster syndrome" characterized by temporary confusion and disorientation, probably affects the majority of the population after a major

---

* This article is based on the report of a seminar organized by the International Hospital Federation, the International Union of Architects, the Office of the United Nations Disaster Relief Co-ordinator (UNDRO) and the World Health Organization (WHO), which was held in collaboration with the League of Red Cross Societies, the International Civil Defense Organization, and the Government of the Philippines at Manila from 13 to 17 March 1978. A limited number of copies of this report are available, on request, from Resource Group, Strengthening of Health Services, World Health Organization, 1211 Geneva 27, Switzerland. Reprinted from WHO *Chronicle*, vol. 34, No. 3 (March 1980), pp. 96-100.

disaster, but rapidly disappears. Secondly, various forms of anxiety/depression occur among those who are predisposed to such conditions. Hysteria is not common.

Exposure is a problem, but the risk of death from exposure following a disaster on land appears to have been exaggerated. Food shortage is another major problem, particularly following floods, which may salinate fields and damage stored or standing crops.

One may observe that in each type of disaster under consideration, the types of health problems which will be of importance are relatively predictable on the basis of knowledge of the terrain and the type of event involved. In the case of earthquakes there will be a large influx of casualties in the first few days, with mainly minor injuries and a possible predominance of the young and old among the injured. The risk of secondary disaster, such as fire, and the resulting pattern of injury (burns), should be allowed for. Floods, tidal waves, cyclones and volcanic eruptions will cause few traumatic injuries even when the death toll is high. Epidemics and communicable disease are of low probability although these remain a potential threat. The risk can be eliminated by prompt attention to likely sources of outbreaks, e.g., sewage and water supplies.

B. National response to disaster

Following a disaster there is usually a lack of reliable, specific information on the extent of damage and of medical needs. The rapid acquisition of accurate information or of estimates of known accuracy are prerequisites both for the planning of a national relief programme and for guiding international assistance.

Two broad categories of information are required by health administrators:

(1) General data about the extent of damage, the area and population affected, functional damage to public services, telecommunications, highways and roads, power and other utilities;

(2) Specific medical, epidemiological, and administrative information on health problems and available resources.

No universal answers can be given as to the precise health information which will be needed, nor on the most effective and least costly methods of collection. The solution most suitable to local conditions must be selected and measures for implementation included in the pre-disaster plan of operations.

Certain types of data have been shown to have practical value following recent disasters:

(1) The *number and proportions (or rates) of injuries* need to be specified. The most pragmatic classifications are based on the site (e.g., fractures of arms or legs) or the severity of trauma.

(2) The *risk of outbreaks of communicable diseases* is usually of major concern. A quick survey of the site of impact will provide baseline data and should lead to the setting-up of an epidemiological surveillance system based on reporting of suspected cases of selected diseases.

(3) A detailed *inventory of functional health facilities* will include much information not included in a general survey of damage. For relief purposes, the emphasis is placed on describing the damage to existing facilities. A quick survey of medical supplies available at the site of the disaster may indicate that urgently needed drugs or material could be easily salvaged and used. The assessment of available supplies should not, however, be limited to the site of the disaster, but should, if necessary, be carried out at the national level. The inventory of essential services available should also include those both within and outside the stricken area.

(4) Health problems are not limited to the management of mass casualties. The provision of water and repair of damaged water supplies and sanitation systems are also important. A *survey of the water supply systems* in urban or rural areas should be included in the early assessment of health needs.

The objective of all assessment is to determine which human or material resources will be required to cope with the emergency. Time is very important; unless these resources are readily and promptly made available, it may be too late for them to be useful. For example, after an earthquake, first aid and surgical supplies must be delivered within the first few days to outlying health services.

The international community is not generally able to respond so quickly. Thus, the responsibility and authority for conducing an assessment of needs lie with the Government of the disaster-affected country. Should the national resources be found insufficient for relief, external assistance from bilateral or international sources will have to be sought. However, when a disaster is of such magnitude as to make extensive international aid necessary, it often happens that nationals with the necessary expertise are too scarce to conduct an adequate assessment of the extent of the damage and of the needs. Consequently, teams or individuals are frequently sent to the affected area by each outside organization involved, to carry out an independent survey and provide first-hand data on the requirements. The participation of the international community in a joint assessment of disaster situations, under the authority of the affected country, would greatly contribute to a better and more efficient response to the challenge of natural disasters.

After an adequate assessment is made, appropriate measures must be initiated in different areas. Methods employed in the surveillance and control

of communicable disease in the wake of a disaster do not differ from those used in normal times, only a more intensive application of these may be needed because of the increased risk of disease transmission. Experience shows that in disasters there is a tendency to rely heavily on vaccination. Participants at the seminar were of the opinion that attempts at mass vaccination under such circumstances appear to be inappropriate. The public, however, may expect to be vaccinated.

1. *Management of mass casualities*

The management of mass casualities can be divided into four phases: the rescue of casualties, first aid, transport and definitive treatment. It was clear that few global solutions could be found to the problem of providing services in these phases, given the great range of resources, type of disaster, and risk in different countries and regions of the world. Some general principles and problems did, however, emerge. For example, in the wake of large-scale disasters, the rescue in most instances must of necessity be performed by the people themselves, as it would be beyond the ability and resources of any central organization to accomplish this task.

With regard to first-aid delivery at the site, it was noted that a reduction in mortality in the severely injured can be achieved by early first aid. The better the equipment used, the greater will be the reduction. Improved knowledge in the community of basic first aid (e.g., the arrest of haemorrhage) and better use of local medical and paramedical personnel are extremely important.

Similar conditions apply to transport. Following a major disaster, most transportation is organized by local people. In some areas, more sophisticated means will be required (e.g., helicopters for the evacuation of those seriously injured). This should and can be planned for in order to achieve systematic coverage of the area, to ensure that only casualities requiring evacuation are evacuated and to ensure that the required information about the patients accompanies them.

2. *Hospital organization*

The subject of hospital organization and disaster plans was given considerable attention. Participants agreed that a written hospital plan, if realistically drawn up, is of considerable advantage. The plan should be devised to meet a variety of probable contingencies which may have to be faced by the hospital.

The plan should be simple, aiming at establishing an optimum distribution and layout of material and personnel to meet an expected need. Two different categories of plans were considered necessary. First, a minor plan would be put into operation for a small caseload, up to approximately 100 casualties, not requiring extensive surgery. This plan would allow the extra load to be dealt with while the hospital continued its normal operation. Secondly, a major plan would be implemented when it was necessary to stop the normal work of the hospital, expand surgical capacity etc., to handle disaster-related injuries.

While it is not possible to plan hospital facilities taking into account all possible disasters, it is desirable to maximize utilization of existing facilities in the event of a catastrophe. The planning of such utilization should take into account that hospitalization is a process comprising a series of stages (reception, sorting of patients according to urgency, diagnosis, treatment, housing), at each of which problems may occur. Therefore, the prerequisite for maximum utilization is that the disaster plan should include a study of each of these stages as well as of the passage from one stage to another.

3. *Drug and medical supplies*

The problem of the efficient provision of drug and medical supplies during the emergency phase of a disaster relief operation was studied. The experience of the League of Red Cross Societies has shown that major difficulties often arise due to lack of co-ordination and standardization of medicines and simple medical equipment. A standardized drug list was developed by a committee of representatives from national Red Cross Societies, the International Committee of the Red Cross, WHO, United Nations Children's Fund (UNICEF), and non-governmental organizations involved in disaster relief. The purpose of the list is to facilitate advance preparation of supplies and standardization of requests for replacement of stocks.

WHO has also established a model list of essential drugs[1] with the aim of facilitating the supply of necessary medicaments of known value at lower cost. In emergency relief operations WHO encourages the use, as far as possible, of drugs from this list in disaster situations, although it is not particularly aimed at emergency situations. It does not replace the Red Cross list or any other list.

A centralized inventory of available supplies and urgently sent drugs is desirable for better co-ordination of supply and distribution within the disaster area. The delivery of drugs to the affected country is less of a problem than is the distribution of the right drugs to the right places within the affected country.

C. International response to disaster

The provision of international assistance can be seen from three points of view: planning, mobilization and co-ordination. The arrival of international aid after

---

[1] See *The Selection of Essential Drugs*, second report of a WHO Expert Committee, WHO Technical Report Series No. 641, 1979.

a disaster can be anticipated, and plans can be made in advance for handling it. Aid is of four well defined types: bilateral aid, arranged directly between the donor and receiving Governments; aid from the numerous voluntary and charitable agencies; aid from various organizations of the United Nations system; and, direct contributions from private individuals, especially where strong links (e.g., ethnic) exist with the stricken country. Most organizations and donor Governments welcome predisaster planning, since in practice they are often forced to respond only after a disaster has occurred and without the benefits of an established programme.

At the international level, co-ordination of international assistance is the responsibility of UNDRO, which aims at having as complete an inventory as possible of material available from different sources.

Participants at the seminar agreed that while international aid is of course welcome, there are a number of regularly recurring problems which need to be solved. For example, the quantity of material donated may sometimes be too great for the capacity of the transportation systems of the country. Donors, whose responsibility ends at the port of delivery, do not always realize that the usefulness of aid depends on distributing small quantities of specific items within the country. Furthermore, the types of drugs supplied were often useless for emergency care, and all too frequently were approaching or had passed their expiry dates. In addition, the difficulty caused by the reluctance of voluntary agencies to merge into a larger co-ordinated group, for fear of losing their identities, was cited.

D. The role of the Government

After a natural disaster, the health facilities' services may have to operate independently, but a central system of control, co-ordination and supply is essential. This will generally be the responsibility of the civil administration, which may, in turn, call upon the services of others, including the Ministry of Health. At the seminar a general scheme for a civil defence operations centre was presented and the Philippine Government's Emergency Operations Centre was visited. Such centres are intended to facilitate the central control of disasters and the appropriate management of available resources.

E. Hospitals and disaster

Hospitals occupy a special place in the life of any community. They are generally located in areas of high population density; they form a focus in the community to which people gravitate at a time of need; they function continuously and even in normal times they respond to emergencies. Moreover, they are generally self-sufficient in their internal provision of services. To improve the resistance of a region or city to disaster, a first priority should be placed upon appropriate planning of the medical facilities. Such plans are relatively easy to implement and may be highly effective.

Ideally, hospitals should be situated away from high-risk areas. The construction and internal design of hospitals should reflect an awareness of such factors as access and the evacuation of patients in case of disaster. The hospital should have reserve sources of essential utilities (e.g., electricity, water supplies).

F. Reconstruction of health services

The approach to reconstruction will depend on a number of factors which will vary according to each disaster and each community concerned. Nevertheless, there are some points, practical as well as conceptual, which can be generalized.

In the health sector reconstruction implies the restoration of all health activities interrupted or reduced by the disaster, and refers to physical reconstruction and to administrative and organizational inputs, both of which are indispensable for the renewed functioning of the health services.

It is now widely recognized that health is in many ways dependent on other services, such as sanitation, agriculture, transport and education. Disasters, with the major disruptions that they cause in all sectors, provide an opportunity to use an intersectoral approach to bring about basic changes during the reconstruction phase.

A natural catastrophe tends to lead to a sense of solidarity within a community and with national and international agencies and Governments of other countries; the ultimate responsibility for reconstruction rests, however, with the Government of the affected country. International aid is a complement to the national effort.

In reconstruction after disaster a distinction is usually made between the emergency, rehabilitation and reconstruction phases. A balance must be maintained with regard to the conflicting priorities of the short, medium and long term.

In the initial stages of reconstruction it is necessary to provide basic services for the survival of the population. The area must be cleared, materials salvaged for reuse, ruins demolished, crops harvested and the flow of necessary supplies re-established. Although the provision of health services is necessary at this time, it is not a central preoccupation (with the exception of an epidemiological surveillance system and the control of infectious diseases). Often, normal services are interrupted and the protection of the population is a necessity. Those services should therefore be re-established as soon as possible. Basic services can be provided from temporary facilities with the support of institutions outside the affected area.

A second stage, which will serve as reference point for future development, is characterized by the development of a basic set of services and the restoration of the unity of the health system.

The process of planning health services includes four steps: diagnosis, formulation of plans, preparatory action and execution of plans. Diagnosis entails identification, description and assessment of the damage caused. It must include a description of the original conditions of the health services as well.

Formulation of plan involves the determination and presentation of those actions which are necessary to modify the observed situation and to bring the services to the proposed level. It should, as far as possible, be a quantified statement of the actions required to produce specific ends.

Preparations for the implementation of the plan include the adoption of new legislation, the introduction of new administrative measures, and the development of criteria for the evaluation of programmes.

To ensure proper execution of the plan an appropriate body must be in charge of co-ordinating the programmes of different sectors and agencies. It must be invested with sufficient authority to control the activities of the organizations involved and must have the legal and administrative resources to do so.

While it is not possible to develop blueprints for action in the aftermath of a disaster which are applicable to every situation, many generalizations can be made. It is clear that the unfortunate destruction following a disaster can provide the opportunity for reconstruction based on more rational principles.

VIRUSES IN DRINKING WATER*

Numerous studies have shown that viruses representing a wide variety of the human enteric virus types can be isolated from unprotected surface waters (2, 6). The vast majority of these viral particles are thought to enter these waters via domestic wastewater. Even though public interest and current legislation may soon result in secondary treatment of all wastewaters before stream discharge, these effluents will not be virus free. Well-operated secondary treatment facilities typically remove about 90 to 99 per cent of the viral content of raw wastewater (5). Studies with seeded virus have indicated that adequate disinfection and tertiary treatment could reduce the viral numbers an additional 90 to 99.99 per cent. However, naturally occurring viruses have been isolated from tertiary effluents, indicating that anticipated reduction may not always be achieved (31).

Although viruses are unable to multiply in the aquatic environment, the protein coat of enteric viruses is remarkably resistant to environmental degradation, thereby protecting the infectivity of the encapsulated nucleic acid for an extended period. The survival ability of these viruses has been demonstrated by their isolation from surface waters at treatment plant intakes distant from known upstream pollution sources (6). Such isolations demonstrate the potential for the entry of viruses into drinking water supplies. The actual occurrence of waterborne outbreaks of viral diseases, such as hepatitis A and acute gastroenteritis, caused by the ingestion of contaminated drinking water is also well documented (19). Many waterborne outbreaks are investigated by local and state health personnel with assistance when needed from the federal Center for Disease Control and the United States Environmental Protection Agency. These investigations consistently reveal as the likely cause of the outbreak either wastewater contamination of the treated water in the distribution system or inadequate source water treatment (14, 22). The method to prevent these explosive epidemics of waterborne viral disease apparently is to be found in the conscientious application of known and accepted sanitary engineering principles of safe drinking water production and distribution.

1. Research Concerns

A major question that has been raised for research and study is whether accepted water treatment procedures allow the transmission of viruses that could contribute to the endemic level of viral infections in a community (8). The penetration of low numbers of viruses into the finished water would mean that viable particles could be ingested at random by individuals who consume the water. Depending upon their susceptibility and the number of particles ingested, some of these individuals could become infected. Such waterborne infections would be produced by relatively low doses of viruses. Even though very few clinical cases of disease would be manifested at the low exposure level, infected individuals would shed large numbers of virus particles. Individuals having close contact with these focal cases may thereby become infected by person-to-person transmission of virus particles that could produce cases of overt disease. In this hypothetical transmission pattern the role of water in maintaining the endemic level of viral disease in the community would not be apparent. There is no firm evidence to support this hypothesis but such an occurrence can be conjectured from the circumstantial evidence. The following summary lists the bases for concern that viral disease may be transmitted by drinking water:

(a) Human enteric viruses can survive for extended periods in the aquatic environment and these viruses have been readily isolated from wastewater and polluted surface water used as source water for treatment plants.

(b) Laboratory data have shown most enteric viruses to be more resistant than indicator bacteria to inactivation by water disinfectants.

(c) Infectivity tests have shown that human infections could be caused by one cell culture dose of poliovirus under experimental conditions.

(d) A consistently high endemic level of hepatitis A occurs in the United States, and investigations have shown contaminated water to be a source of hepatitis A outbreaks.

(e) Sporadic outbreaks of nonbacterial gastroenteritis suspected of being waterborne occur rather frequently, and an endemic level of gastroenteritis occurs in the United States; waterborne viruses possibly may be responsible.

(f) Increased water demand is making direct recycling of waste water almost a reality for some water systems, and conventional water treatment is not designed to produce potable water from wastewater.

The possibility of endemic waterborne viral disease transmission via conventionally treated water

---

* From the Report of the American Water Works Association (AWWA) Committee on Viruses in Drinking Water. Reprinted from *Journal* AWWA, vol. 71, No. 8 (August 1979), pp. 441-444, by permission. Copyright 1979, the American Water Works Association.

has been a concern of some water purveyors, public health officials, environmental virologists, and sanitary engineers for several years. The observed failure of the water quality bacterial indicator system to indicate consistently the absence of viruses in water samples, coupled with the bacterial indicator's greater susceptibility to chlorine disinfection, has tended to underscore this concern (10). However, the actual occurrence of such a transmission pattern for viruses has been extremely difficult to confirm and, of course, negative data cannot be considered as proof of the absence of such an occurrence. Two approaches have been proposed for evaluating the hypothesis: (a) to test large volumes of finished water for viruses with sensitive virus recovery procedures, and (b) to conduct epidemiological studies of viral disease in populations that consume treated surface waters. Many investigators believe that the latter approach will not yield a conclusive answer. It is felt that epidemiological procedures are not sensitive enough to identify, in a freely moving population, the infections or cases of disease that may be derived from viruses transmitted by drinking water vs cases resulting from other routes of exposure. Therefore, major attention has been focused on the former approach.

Research efforts in many laboratories around the world have been (and remain) directed toward the development, improvement, and evaluation of viral concentration systems that will recover low numbers of virus particles from large volumes of water. The many batch concentration systems that have been devised over the years have tended to give way to a flow-through system because of the relative ease with which greater volumes of water could be processed. In recent years the basic principles of a flow-through procedure have received rather widespread acceptance by those working in this field and have yielded a standardized procedure that was published in 1976 (42). (An updating and expansion of standardized viral recovery procedures for various types of waters will be included in the 15th edition of *Standard Methods for the Examination of Water and Wastewater*, to be published in the near future). The flow-through concentration procedures have routinely been used to process water samples up to a volume of 1900 l (500 gal). Farrah and others (17) have suggested that volumes approaching 100,000 l may be processed with a system tested in their laboratory. However, the viral recovery efficiency of the system with such large volume samples has not been thoroughly evaluated, and results of field sampling of volumes in excess of 1900 l have not been reported.

2. *Treatment Effectiveness*

It is generally accepted that the coagulation-sedimentation and filtration steps of water treatment are capable of removing about 99 per cent of the viruses present in the source water (41). This level of reduction is considered inadequate to provide the necessary margin of safety needed to prevent the transmission of infectious agents through drinking water that is produced from unprotected surface water sources. The major line of defence to provide this protection has been the disinfection step, currently synonymous with chlorination for most water treatment systems in the United States. Chlorine is an effective viricide for freely suspended virus particles under defined conditions of pH and chlorine species (28, 29). Under rigidly controlled experimental conditions Engelbrecht and others (15) have recently tested the chlorine susceptibility of six enteric viruses. They observed a 99 per cent reduction in infectivity within 3.4 min and 96 min for the most resistant of the six viruses at a free chlorine concentration of 0.5 mg/l and pH levels of 6 and 10, respectively. The major chlorine species that occurs at the lower pH (hypochlorous acid) was found to be a more potent viricide than the chlorine species that occurs at the higher pH value (hypochlorite ion). Combined chlorine species have been found to be considerably less viricidal than the hypochlorite ion (27).

None of the cited chlorine inactivation studies included the waterborne virus of major concern, hepatitis A virus (HAV). The absence of a cell culture system that will support the replication of the virus and the high cost and scarcity of susceptible laboratory animals have severely limited the study of this important disease agent. However, definitive chlorine inactivation data for HAV may soon be available. A study is currently underway in which HAV infectivity will be determined by administering preparations exposed to chlorine to marmoset monkeys (25).

Seeded studies with laboratory-cultivated viruses have indicated that the conventional water treatment process – i.e., coagulation-sedimentation, filtration, and disinfection – can remove or inactivate six to eight orders of magnitude of viruses (40). Assuming a 10^8 reduction, a treated water supply using a polluted source water that contains a reasonable load of one unit of virus per litre of water at the plant intake would contain one viable unit of virus in 100 million litres of finished water. If the results of these seeded studies were truly representative of the field situation, then isolating viruses from the typical 1900 l sample volume would be rare indeed.

Some investigators have felt that conventional water treatment may not yield such high levels of reduction of naturally occurring viruses. Their reservations have given significant impetus to the initiation of viral testing of water samples of relatively small volumes of a few hundred litres. Recent observations have provided technical bases for this concern. The results of a study with a rotavirus suggested that some viruses may not be removed by the coagulation-sedimentation treatment step as readily as is the virus frequently used in treatment evaluations, poliovirus 1 (16). Of greater concern has been an increasing body of data

suggesting that chlorine disinfection may not be as effective a viricide for naturally occurring viruses as studies with laboratory-cultivated seeded viruses have indicated. A large percentage of naturally occurring viruses can be associated with particulate matter (21). This association has been found to enhance the survival and chlorine resistance of absorbed viruses over those of free virus particles (10, 26). In addition, Scarpino and others (38) showed that under certain experimental conditions (the presence of 0.05 moles per litre potassium chloride), the hypochlorite ion may be seven times more effective in inactivating poliovirus than hypochlorous acid. The influence of potassium chloride on the chlorine inactivation of viruses has been confirmed by Engelbrecht and other (15), and if similar types of reactions are shown to occur during water treatment, the conditions for optimum water disinfection with chlorine may be obscured. Using poliovirus 1, Bates and others (4) reported results of a laboratory study that suggested that the viral progeny of the fraction that remained viable after repeated exposure to chlorine may have become innately more resistant to chlorine inactivation. Some poliovirus suspensions prepared from field isolates have been reported to be somewhat more chlorine resistant than laboratory strains of the virus tested under similar conditions (16).

3. *Viral Analyses of Treated Water Samples*

Most of the findings indicating that conventional water treatment could be inadequate for virus removal and inactivation are preliminary and have not been extended by the reporting investigators or confirmed in other laboratories. Therefore, the practical importance of these observations is unknown and must await further evaluation. However, the need for drastic changes in water treatment as a result of these reports has not been generally suggested by the result of viral analyses of drinking water. Table 1 summarizes reports gleaned from the world literature on viral isolations from treated drinking water. The actual water quality and water treatment conditions at the time viruses were reported to have been isolated from these supplies were not stated in most of these reports. Therefore, a blanket indictment of the stated water treatment procedures for failure to provide adequate protection from the waterborne transmission of viruses should not be made. Some of the positive findings are controversial, and questions of authenticity have been raised by reporting investigators and others (3, 12, 9). However, some investigators have vigorously supported the validity of their findings (30).

Perhaps the most extensive field study yet undertaken is being performed by the EPA Environmental Research Center in Cincinnati. Since 1972 EPA has collected and analysed 255 drinking water samples from water supply systems in 56 communities. An additional 50 treated-water samples have been analysed from a single community system that utilized a heavily polluted surface water source. Most of these 305 samples were processed by the tentative standard method (42), the volume of most samples was about 1900 l. No viruses were isolated from any of these samples (1).

The total number and volume of drinking water samples that have been analysed for viruses are not known. Considering the large number of water systems, variations in treatment, quality of pretreated water sources, and the total volume of water consumed, there is need for much more sampling to determine the occurrence of viruses in drinking water. Of interest is the indication that 10 virology laboratories throughout the world plan to continue or to initiate viral analyses of drinking water in the respective countries (11).

4. *Limitations of Virus Methodology*

The efficiency of the tentative standard method as well as other virus recovery procedures is far from 100 per cent recovering all viruses present in a water sample. At best, these procedures represent the current state of the art, and limitations in their viral concentration capability have been reported (37, 45). The inability of cell culture assay systems to recover all known enteric viruses – e.g. hepatitis A, acute gastroenteritis agents, and coxsackie viruses A – has long been recognized. These limitations notwithstanding, the data obtained from these field studies are currently the best available evidence for evaluating the health risk of viruses in drinking water.

5. *Treatment Recommendations*

In the absence of definitive evidence to the contrary, it appears to the committee that conventional treatment (coagulation-sedimentation, filtration, and disinfection) of contaminated surface waters that meet the current minimum microbial standard of quality (43) will provide reasonable assurance of a virologically safe drinking water. Treatment should produce a finished water with a consistent turbidity level of <1.0 NTU (Nephelometric Turbidity Units). Appropriate chlorine disinfection of the clarified water may be achieved by maintaining a free chlorine residual of 1.0 mg/l for at least 30 min at a water pH not to exceed 8. Prudence would dictate that drinking water derived from protected surface water and ground-water sources should also receive this level of disinfection to protect against unforeseen pollution occurrences. Increased chlorine concentration upward to 2 mg/l or increased contact time to a few hours under the same pH restraints will substantially increase the margin of safety. A reduction in contact time or an increase in pH should be compensated for by an appropriate increase in free chlorine residual. A free chlorine residual of 0.2 mg/l should be maintained throughout the distribution system to minimize the health risk from possible recontamination of the treated water.

Table 1. Reported isolations of human viruses from treated drinking water

Virus adsorbent	Virus type isolated	Number samples positive / Number samples collected	Water treatment	Location and date	Reference
Gauze pad	polio, other enterics	48/553	disinfection	France 1960-62	Coin et al (13)
Gauze pad	reo, entero	2/25	complete[a]	France 1961-63	Foliguet et al (18)
Gauze pad	coxsackie A	2/65	complete	Rumania 1962-71	Nester and Costin (32)
Anionic resin	coxsackie A and B, echo, polio	9/64	complete	USSR 1968-71	Rabyshko (36)
Hydroextraction and two-phase polymer	reo, echo, polio	7/64	complete	Massachusetts 1969-71	Fri and McDermott (20)
Two-phase polymer and ultrafiltration	reo, entero	2/NR[b]	complete[c]	South Africa 1971	Nupen and Stander (33)
Two-phase polymer	reo?	1/464	complete	South Africa (NR)	Grabow and Isaacson (23) (and personal communication)
Polyelectrolyte (PE60)	nonpolio, entero	NR	complete[d]	Italy (NR)	Petrilli et al (35)
Hydroextraction and two-phase polymer	polio	1/7	complete	Massachusetts 1972-73	Clarke et al (12)
Cellulose nitrate membrane filter	echo	1/10	disinfection	Florida 1975	Wellings et al (44)
Fiberglass and asbestos filters	polio	4/12	complete	Virginia 1975	Hoehn et al (24)
Fiberglass and asbestos filters	polio	1/42	complete	Virginia 1976	Berry and Shaffer (9)

a/ Complete treatment in general was coagulation-sedimentation, rapid filtration, and disinfection.

b/ NR - not reported

c/ Further chlorination received before distribution; no viruses recovered after final treatment.

d/ An experimental plant that used complete treatment of a heavily polluted source water; finished product was not consumed.

6. *Alternative disinfectants*

Concern over an increase in concentration of potentially harmful halogenated hydrocarbons in drinking water as a result of chlorine reaction with organic matter in the source water has stimulated interest in other water disinfectants. Ozone and chlorine dioxide are rather widely used in Europe and may find increased use in the United States in the future. Both are potent viricides and under proper conditions may be even more effective than free hypochlorous acid (27). In the absence of a germicidal residual when ozone alone is used, a preferred system may be ozonation for primary disinfection plus low level chlorination as a final step for maintaining a residual throughout the distribution system. However, before any new system can be recommended, the possible production of harmful reaction products must be fully evaluated. A report on these and other aspects of alternatives to chlorine disinfection of drinking water has been recently prepared (34).

Conclusions

Water treatment criteria for the production of virologically safe drinking water must continually be re-evaluated, especially since significant changes in chlorination practice may be implemented to reduce the production of halogenated hydrocarbons. Treatment criteria for the direct production of potable water from wastewater, a distinct possibility for some communities in the United States within the next few years, must be carefully developed and fully evaluated. The viral quality of groundwater must be continually assessed as a result of increased land application of wastewater and sludge.

Environmental virology is an active area of research, and studies are continuing to develop better virus recovery procedures and to obtain more definitive data as to the effectiveness of treatment procedures and the true waterborne disease health risk. As techniques become available for the routine laboratory cultivation of the potentially waterborne agents of viral gastroenteritis, hepatitis, and possibly other yet unidentified pathogenic agents, procedures for their control must be evaluated. It now appears that full conventional water treatment with optimum conditions consistently maintained will provide reasonable assurance of a virologically safe finished drinking water. Perhaps the greatest reduction in the number of cases of waterborne viral disease would result from a more widespread application of such treatment, coupled with greater diligence in protecting the integrity of distribution systems.

Bibliography

1. Akin, E.W. Viruses in drinking water. The United States Environmental Protection Agency (USEPA) *Survey* (in press).

2. Akin, E.W., Benton, W.H. and Hill, W.F., Jr. Enteric viruses in ground and surface waters: A review of their occurrence and survival. *Virus and water quality: Occurrence and control*, Proceedings of the Thirteenth Water Quality Conference, Urbana, University of Illinois, 1971.

3. Akin, E.W. and Jakubowski, W. Viruses in finished water: The Occoquan experience. Proceedings of the Water Quality Technology Conference, 1977. Denver, American Water Works Association, 1977.

4. Bates, R.C., Shaffer, P.T.B. and Sutherland, S.M. Development of Poliovirus having increased resistance to chlorine inactivation. *Applied and Environmental Microbiology*, 34:6:849 (1977).

5. Berg, G. Removal of viruses from sewage, effluents and waters: 1. A Review. *Bulletin of the World Health Organization*, 49:451 (1973).

6. Berg, G. Viruses in the environment: Criteria for risk. *Risk assessment and health effects of land application of municipal wastewater and sludges.* Proceedings of the Conference at University of Texas, San Antonio, Texas, 1978.

7. Berg, G. Virus transmission by the water vehicle: 1. Viruses. *Health Laboratory Science*, 3:2:86 (1966).

8. Berg, G. and Metcalf, T.G. Indicators of viruses in waters. *Indicators of viruses in water and food*, edited by G. Berg. Ann Arbor, Michigan, Ann Arbor Science, 1978.

9. Berry, J.W. and Shaffer, P.T.B. Viruses: Monitoring is the key. *Water Wastes Engineering*, 15:15 (1978).

10. Boardman, C.D. and Sproul, O.J. Protection of viruses during disinfection by absorption to particulate matter. *Journal* of the Water Pollution Control Federation (WPCF), 49:1857 (1977).

11. Clarke, N.A. Public health aspects of viruses in water, Vol. 6. Cincinnati, Ohio, USEPA, August 1977.

12. Clarke, N.A. and others. Virus study for drinking-water supplies. *Journal* American Water Works Association (AWWA), 67:4:192 (April 1975).

13. Coin, L. and others. Modern microbiological and virological aspects of water pollution. *Advances in Water Pollution Research*, edited by O. Jaag. Oxford, Pergamon Press, 1964.

14. Craun, G.F. and McCabe, L.J. Review of the causes of waterborne-disease outbreaks. *Journal* AWWA, 65:1:74 (January 1973).

15. Engelbrecht, R.S. and others. Virus Sensitivity to Chlorine Disinfection of Water Supplies. EPA-600/2-78-123, Cincinnati, Ohio, USEPA, 1978.

16. Farrah, S.R. and others. Comparison between absorption of Poliovirus and Rotavirus by aluminum hydroxide and activated sludge flocs. *Applied and Environmental Microbiology*, 35:2:360 (1978).

17. Farrah, S.R. and others. Regeneration of pleated filters used to concentrate Enteroviruses from large volumes of tap water. *Applied and Environmental Microbiology*, 33:308 (1977).

18. Foliquet, J.M., Schwartzbrod, L. and Gaudin, O.G. La pollution virale des eaux usées, de surface et d'alimentation. *Bulletin* of the World Health Organization, 35:737 (1966).

19. Foodborne and waterborne disease outbreaks: annual summary 1975. Center for Disease Control. Department of Health, Education and Welfare Publication (CDC) 76-8185 (1976).

20. Fri, R.W. and McDermott, J.H. Hearings before the Committee on Commerce, United States Senate, 92nd Congress. Serial 92-57, 20 March 1972. United States Government Printing Office, 1972.

21. Gerba, C.P., Stagg, C.H. and Abadie, M.G. Characterization of sewage solid-associated viruses and behavior in natural waters. *Water Research* 12:10:805 (1978).

22. Goldfield, M. Epidemiological indicators for transmission of viruses by water. *Viruses in Water*, edited by G. Berg and others. Washington, DC, American Public Health Association (APHA), 1976.

23. Grabow, W.O.K. and Isaacson, M. Microbiological quality and epidemiological aspects of reclaimed water. *Progress in water technology*, 10:1-2 (1976).

24. Hoehn, R.C. and others. Trihalomethanes and viruses in a water supply. *Journal of the Environmental Engineering Division*, American Society of Civil Engineers (ASCE) 103:803 (October 1977).

25. Hoff, J.C. Personal communication, Cincinnati, Ohio, USEPA, 1978.

26. Hoff, J.C. Relationship of turbidity to disinfection of potable water. *Evaluation of microbiological standards for drinking water*, edited by C.W. Hendricks, EPA-570/9-78-000. Washington, DC, USEPA, 1978.

27. Hoff, J.C. and Geldreich, E.E. Alternative disinfectants for drinking water – ozone, chlorine dioxide, chloramines. Proceedings of the 20th Anniversary of the Public Water Supply Engineers Conference; Part 3, Water Treatment. Urbana, University of Illinois, 1978.

28. Kabler, P.W. and others. Viricidal efficiency of disinfectants in water. *Public Health Reports*, 76:7:565 (1961).

29. Liu, O.C. and others. Relative resistance of twenty human enteric viruses to free chlorine in Potomac waters. *Virus and Water Quality: Occurrence and Control.* Proceedings of the 13th Water Quality Conference. Urbana, University of Illinois, 1971.

30. Metcalf, T.G., Shaffer, P.T.B. and Mooner, R. Incidence of virus in water: Case histories. Proceedings of the AWWA 98th Anniversary Conference. Denver, Colo., 1978.

31. Miele, R.P. Pomona virus study – Final report. Sanitary District of Los Angeles County, Whittier, California, 1977.

32. Nestor, I. and Costin, L. Presence of certain enteroviruses (coxsackie) in sewage effluents and the river waters of Rumania. *Journal of Hygiene, Epidemiology, Microbiology and Immunology*, 20:2:137 (1976).

33. Nupen, E.M. and Stander, G.J. The virus problem in the Windhoek Waste Water Reclamation Project. *Advances in water pollution research*, edited by S.H. Jenkins. New York, Pergamon Press, 1973.

34. Ozone, chlorine dioxide and chloramines as alternatives to chlorine for disinfection of drinking water: State-of-the-art. Office of Research and Development, Cincinnati, Ohio, USEPA, 1978.

35. Petrilli, F.L. The virological monitoring of water: 1. Drinking water. *Boll. Ist Sieroter Milan*, 53:3:434 (1974).

36. Rabyshko, E.V. Certain problems of the circulation of enteroviruses in the environmental objects. *Gigiena i Sanitariya*, 39:105 (1974).

37. Rutala, W.A. and Sobsey, M.D. Evaluation of the tentative standard method (TSM) for detecting parvoviruses in tap water. Abstracts of the Annual Meeting of the American Society for Microbiology (ASM), 1978. Washington, DC, ASM, 1978.

38. Scarpino, P.V. and others. A comparative study of the inactivation of viruses in water by chlorine. *Water Research*, 6:959 (1972).

39. Shaffer, P.T.B., Metcalf, T.G. and Sproul, O.J. Chlorine resistant viruses from drinking water. Presented at American Society of Civil Engineers (ASCE) National Environmental Engineering Conference, Nashville, Tenn., Vanderbilt University, July 1977.

40. Sobsey, M.D. Enteric viruses and drinking-water supplies. *Journal* AWWA, 68:8:414 (August 1975).

41. Sproul, O.J. Removal of viruses by treatment processes. *Viruses in water*, edited by G. Berg and others. Washington, DC, APHA, 1976.

42. Standard methods for the examination of water and wastewater, 14th edition. Washington, DC, APHA, AWWA, and WPCF, 1976.

43. Water quality criteria 1972. A report of the Committee on Water Quality Criteria. USEPA, 1972.

44. Wellings, F.M., Mountain, C.W. and Lewis, A.L. *Virus in groundwater.* Proceedings of the Second National Conference on Individual Onsite Waste-water Systems. Ann Arbor, Michigan, National Sanitary Foundation, 5-7 November 1975.

45. Williams, F.P., Jr. and Jakubowski, W. Large volume virus concentration: Evaluation of the organic flocculation method for elution/reconcentration. Abstracts of the Annual Meeting of the ASM, 1978. Washington, DC, 1978.

SIGNIFICANT METEOROLOGICAL EVENTS IN THE ESCAP REGION IN 1979*

A. Asia (including the Union of Soviet Socialist Republics)

1. *Temperature and sunshine*

The establishment and intensification of the Siberian anticyclone caused record low temperatures (6-12°C below normal) in Krasnoyarsk Territory (USSR) and abnormally low temperatures (4-9°C lower than average) in western Siberia during January and February 1979. In western parts of European USSR January was 2-5°C colder than normal; in February the southern Ukraine and the northern Caucasus had a warm spell with temperatures between 12° and 20°C, followed by a cold burst (-10° to -15°C), which caused damage to winter crops and stone-fruit orchards.

Further east, in Japan frequent passages of travelling anticyclones brought unusually high temperatures all over the country during the period January to March. Out of 154 observing stations, 115 recorded either the highest daily maximum or the highest monthly mean temperatures for the three months. To the south, the months of January, February and March were unusually warm in Pakistan and Viet Nam. In Pakistan, a cold spell affected Baluchistan during the first week of March, causing a record minimum of -9°C at Quetta airport. In Viet Nam, daily maxima in February ranged between 34° and 36°C in the interior of North Delta, and between 38° and 39°C in the central provinces. The mean temperature was generally 2-3°C above normal during the period.

April was cold in the European USSR, temperatures being 8-10°C lower the normal in the north, and southern parts experiencing the longest cold spell for 20 years in the second half of the month. May turned suddenly warm, mean temperatures being 3-6°C above normal (the warmest May ever recorded in certain central districts, notably Moscow). India was affected by sporadic heat waves from the last week of April to the middle of August. In Thailand, the months of March, April and May were generally warm. Bangkok had its highest recorded temperature (40.0°C), and temperatures reached as much as 42.7°C at Nakhon Ratchasima to the north-east.

In June, warm weather prevailed in Japan, Pakistan and Viet Nam. The highest daily maxima and mean monthly temperatures were observed at 68 out of the 154 Japanese observing stations. In Pakistan, Jacobabad and lower Sind recorded temperatures of 51°C on 11 June and Karachi had 47°C on 17 June, the highest there for the past 26 years. In Viet Nam the average 10-day temperatures during mid-June ranged between 30° and 31°C in the North Delta, the highest for the past 24 years. June was warm in the south of European USSR, but in the north and east cold weather damaged vegetable crops. Record low temperatures for July were registered in districts near the Baltic, Byelorussia and central areas. Central Asia and Kazakhhstan in the USSR were 2-4° and 6-7°C warmer than normal in October and December respectively. December was also extremely warm in western Siberia, Krasnoyarsk Territory and Yakutsk. But October temperatures were 3-5°C below normal in eastern Siberia, and in November they were 3-6°C below normal in Yakutsk. Early October brought severe frost to parts of Ukraine and Moldavia such as is expected only once in 10-15 years. Damage was caused to certain crops. October to December were colder than normal in Thailand. The lowest temperature of the year over the whole country was 7.3°C registered at Chiang Rai in the far north at the end of December. The duration of sunshine in Hong Kong during October was 297.4 hours, a record since 1884.

2. *Precipitation, floods and droughts*

There were more reports of above-average precipitation than deficits in 1979. During the period January to April, three to six times the average precipitation fell in western Siberia, Krasnoyarsk Territory, and the Baikal area of the USSR. The January and February totals set new records at Krasnoyarsk and Khabarovsk. Much precipitation fell over the southern part of the European USSR from January to April. Melting snow and rain caused rivers to rise by three to five metres in February and flooding occurred in Voroshilovgrad, Zhdanov and Mogilev Podolsky.

Further south, Pakistan and India reported exceptional rainfall events during the period. On 18 February an extratropical disturbance caused 94 mm of rain within six hours at Karachi airport, the heaviest six-hour fall ever recorded in February. January and February were wetter than normal in north-western and central parts of India. In March, April and May spring floods were substantial on numerous rivers in southern European USSR. However, there was a large precipitation deficit in May and June (10-20 per cent of normal) which has a return period of 20-50 years.

---

* From an advance copy of material to appear in the World Meteorological Organization (WMO) *Bulletin*, vol. XXIX, No. 4 (October 1980).

The violence of the precipitation caused some damage to agricultural crops in July; central parts had 200-300 per cent of the normal monthly rainfall.

The month of May was very wet in the Asian part of the USSR and flooding occurred in several districts. Thawing snow caused flooding in the River Irtysh basin, affecting many towns in the plains north-west of Omsk. In the Fergansk basin and Tadzhikistan, thawing snow and frequent rainstorms caused damage to crops, houses and factories. Further east, in the Amur basin, May and June were characterized by rainfall deficits. The low water level of the rivers impeded shipping. Frequent forest fires were observed in the Lake Baikal and Irkutsk districts and in Krasnoyarsk Territory.

The month of May was particularly wet in Thailand, as tropical depressions passed over the country. There were floods which damaged over 1640 km^2 of cultivated land. North-western and central parts of India had above-average rainfall during the month.

Late June and early July were exceptionally wet in Japan. In many western parts of the country, rainfall amounts were the highest since 1953. As a result of the unusually heavy rain 29 people were reported dead or missing and damage was estimated at 118,000 million yen (about $US 484 million). July was wet in European USSR with 200-300 per cent of the normal rainfall, an event expected once every 20-30 years.

Except for north-western parts, India was affected by drought because of a delay in the onset of the monsoon. During a few days in July and the first half of August, a westward-moving monsoon depression produced very heavy rain with consequential severe flooding in the states of Rajasthan, Uttar Pradesh, Bihar, Gujarat and Vidarbha. Very heavy rain over Gujarat during the second week of August caused a reservoir to burst and severe flash floods submerged Morvi and nearby villages. About 1500 human lives and 12,000 head of livestock were lost. Earlier floods in Rajasthan had claimed 250 lives. The total loss of property in these two floods was estimated at $US 150 million. An unusually dry period occurred in upper Thailand in the second half of July and from the end of August to the third week of September. This caused damage to 4204 km^2 of farmland. In the mountainous northern and central parts of Viet Nam, above-average rainfall occurred in June. In many places the monthly total was 150 per cent of the monthly mean. In the south of the country, August was equally wet, 730 mm of precipitation being recorded at Hon Gai (near Haiphong) compared with the mean value of 270 mm. These excessive falls caused serious inundations.

August and September continued rather wet in European USSR, and in the last ten days of October snow lay over a large part of the country, much earlier than usual.

In India in November, floods in Tamil Nadu caused the death of some 160 people and considerable loss of property. In the first half of September, river in the north of Viet Nam were severely affected by floods, but from about 20 September to the end of the year northern parts were affected by drought which reduced agricultural yields. The last quarter of the year was also very dry in Hong Kong, when total rainfall amounted to only 11.4 mm, the second lowest on record. Due to the very dry conditions, numerous hill fires broke out destroying several hectares of vegetation.

3. *Storms and tropical cyclones*

There were 29 tropical cyclones over the eastern North Pacific and the South China Sea during the year. Six of them affected Hong Kong. Of these, typhoon Hope was the most severe storm to affect Hong Kong since 1971. It struck the New Territories on 2 August causing 12 deaths, injuring 260 and rendering 80 people homeless. Flooding was widespread and about 75 per cent of the crops were destroyed or badly damaged. The second most severe was tropical storm Mac. It passed over western Lantau Island during the night of 23 September, claiming one human life and leaving 67 people injured. Many roads were flooded and several minor landslides occurred. The other four were less severe in their consequences. The precipitation associated with the two severe storms brought the total rainfall in 1979 to 16 per cent above Hong Kong's normal. Of the six tropical cyclones to affect India during the year, three attained severe cyclonic intensity. That which hit southern coastal areas of Andhra Pradesh on 12 May caused 1000 deaths and damage amounting to Rs 1700 million ($US 204 million). Tropical cyclone activity in the post-monsoon season in India was less than usual.

Two depressions passed over Thailand during the year. The first originated in the vicinity of the Paracel Islands, and moved towards the coast of Viet Nam, subsequently affecting the extreme north-east on 9 and 10 August. The second was the former tropical storm Nancy, which affected Viet Nam and moved through northern central Thailand. The two depressions caused floods in many parts of both countries.

From midsummer to autumn, five typhoons affected Japan. Two of these, Owen and Tip, crossed the country causing much damage. Owen arrived on 30 September, causing the death of 11 people and damage valued at 145,000 million yen ($US 5 million). Tip affected Honshu on 19 October, claiming the lives of 115 people and damage estimated at 194,000 million yen ($US 795 million).

As regards extratropical storms, a prolonged severe blizzard occurred in the Urals in the USSR in early and mid-February, blocking roads and railways and prohibiting open-cast mining operations. The lower parts of Leningrad were flooded in mid-Octo-

when a deep depression brought strong westerly winds which caused a surge up the River Neva. On 24-25 December cold air crossing the Caucasus gave rise to locally strong Bora winds averaging 25-30 m/sec and gusting to 38-48 m/sec. Buildings and power lines were damaged.

B. South-west Pacific

1. *Temperature and sunshine*

January temperatures were well above average over much of southern Australia. The mean maximum temperature for the month at Mildura (Victoria) was 36.7°C, which was a record and 4.6°C higher than the long-term average. Canberra also had its hottest January on record; there the mean maximum temperature was 31.9°C, which is 4.5°C above normal. Several places in South Australia and southern parts of Western Australia set new records for extreme maximum temperatures in January such as Ceduna (47.8°C) and Mundrabilla and Forrest (both 49.8°C) in the Nullarbor Plain. Perth recorded its highest ever daily minimum temperature of 29.9°C on 27 January.

In July, the minimum temperature of 2.4°C registered at Carnarvon on the coast of Western Australia and of -1.4°C at Mt. Isa airport in the west of Queensland were both new records, and the lowest ever daily maxima were also recorded at a number of localities in tropical Queensland, including Townsville where the temperature reached only 16.4°C on 28 July. A record absolute minimum temperature was -9.4°C recorded at Mitchell (Queensland) on 15 August.

The mean temperature for the year 1979 was 0.5°C above the 1941-1970 normal in New Zealand, which compares with the recent warm years of 1970, 1971, 1974 and 1978.

2. *Precipitation, floods and droughts*

Cyclone Peter was responsible for a new record 24-hour rainfall in Australia, when 1140 mm was registered at Bellenden Ker, about 40 km south of Cairns (Queensland), on 4 January. This helped to establish a new Australia monthly rainfall record at Bellenden Ker where 5387 mm was recorded in January. Birdsville (near the border between Queensland and South Australia) had 128 mm of rain in the 24 hours ending at 0900 on 18 January. This is more than its annual median rainfall of 123 mm. Extensive flooding occurred in many coastal streams in the Cape York peninsula. The Barron River had the third highest flood on record.

June and July were dry over southern Australia, monthly precipitation totals being either the lowest or among the lowest on record in many districts. New records include 1.8 mm at Hobart in June and 9.4 mm at Melbourne in July. Severe rainfall deficiencies developed over much of the south-west of Western Australia during the winter and early spring. Although November rainfall totals were generally higher than normal, it was not sufficient to overcome the deficiencies. In eastern Victoria, some southern and eastern parts of New South Wales and eastern Tasmania, serious rainfall deficiencies built up during winter and spring and continued into the summer.

December was dry over most of New South Wales and much of Victoria. Many localities in New South Wales received little or no rain; only 2.8 mm was measured at Sydney which was a new record for the month, and Cabramurra (in the Australian Alps) had only 9 mm compared with its December average of 97 mm.

Late in January and into February, there was extensive flooding of coastal streams between Rockhampton and Cairns. Further extensive flooding occurred in Queensland during late February and early March due to the effects of cyclone Kerry. Approximately $A 1 million ($US900 000) damage was caused to a recently completed weir on the Burdekin River. Local flash flooding from thunderstorms also caused more than $A 1 million damage at Port Pirie in South Australia on 31 December.

In New Zealand, some areas recorded 20 to 30 per cent more rain than usual, making 1979 the wettest year since 1968. In late November and early December, a strong north-westerly airstream brought heavy and intense rainfall to parts of the South Island high ground. The greatest effect was confined to a narrow belt of the Southern Alps extending from western Southland and Otago to the Waimakariri River in Canterbury.

The Haast River in southern Westland ran extremely high; the peak could not be registered because the recorder was covered by water. Damage in this area to bridges and roads has been estimated at over $US1 000 000. One tributary of the Waitaki system peaked on 2 December at 160 m^3/sec, which has a return period of 50 years, and another, the Ahuriri River, had a peak discharge of 550 m^3/sec six hours later, which has a return period of 100 years. A rain-gauge in the vicinity of Mount Cook recorded a 24-hour total of 537 mm on 3 December, the highest one-day rainfall measured in any month at this station since October 1942 when there was 559 mm.

3. *Storms, tropical cyclones and tornadoes*

As already mentioned, tropical cyclone Peter and its residual rain depression was active in the Gulf of Carpentaria area of Australia at the beginning of January, causing extensive damage in the Cairns area. Cyclone Greta in mid January and Rosa in late February brought gales, rain and some flooding to the Gulf of Carpentaria and northern Queensland regions.

Cyclone Kerry, which had formed to the north-east of the Solomon Islands, crossed the coast of north

Queensland near Proserpine on 1 March, moved out to sea and reintensified, before finally dissipating about 300 km further south-east. Damage was mostly confined to the area near MacKay, affecting pleasure craft moored in the harbour and roads and bridges in an around the town, Kerry was most unusual in that it maintained its tropical cyclone characteristics for nearly three weeks.

Cyclone Hazel formed off the north-western coast of Australia on 7 March. It moved westwards and then southwards down the west coast, finally moving inland south of Carnarvon. A fishing vessel sank on 13 March with the loss of 15 lives. Damage to plantations in the Carnarvon area was estimated at between $A2 and 3 million and to a nearby salt works at between $A3 and 5 million. Other damage to property along the path of Hazel was estimated at more than $A18 million ($US16 million).

Thunderstorms in South Australia on 14 November were described as the most violent and widespread for many years, causing damage estimated at $A20 million ($US18 million). The highest wind gust ever recorded in South Australia (46 m/sec) occurred at Woomera during one of these thunderstorms. Kalgoorlie (Western Australia) had a gust to 39 m/sec in a violent thunderstorm on 7 November, and on 15 November, thunderstorms over south-western suburbs of Sydney caused considerable damage. At Bankstown airport, 10 aircraft were extensively damaged and a further 20 affected to a lesser degree; one building was demolished and another damaged. The gust of 37 m/sec during the storm was the highest ever recorded there. Lismore (about 200 km south of Brisbane) suffered severe storms on 13 December.

At Auckland in the North Island of New Zealand, a combination of high tides and winds gusting to 25 m/sec on 8 October caused the closure of roads in the waterfront area. Yachts broke their moorings and were driven ashore and damaged by strong winds.

WATER: A PERSPECTIVE ON GLOBAL POLITICS*

All the rivers run into the sea,
Yet the sea is not full;
Unto the place from whence the rivers come,
Thither they return again.

Ecclesiastes 1 :7

Introduction

Water, said the Greek philosopher Pindar, as early as the fifth century B.C., is the best of all things. That may perhaps be an overstatement, but it certainly is not surprising, especially when it is considered that water has been one of the most precious commodities throughout man's recorded history. Water makes human, animal, and plant life possible, and without it, life and civilization cannot develop or survive. Wars have been fought in the past over the availability of water, and even now, relations between several countries are strained due to disputes over water.

The entire history of mankind could be written in terms of our need for water. From the very beginning, it was realized that water was an essential ingredient for survival, and therefore, early civilizations developed and flourished on lands made fertile by major rivers – Tigris and Euphrates in Mesopotamia, Nile in Egypt, Indus in India, and Huang-Ho in China. As early as 3000 B.C., the Egyptians had already developed intricate water resources networks, especially irrigation systems. The historian Herodotus provides a vivid description of these early Egyptian water development works, and he was so impressed by the role of the river Nile in the country's survival that he called Egypt "the gift of the Nile".

A. Distribution of Water

Water is considered to be a renewable natural resource since it is continuously being renewed through nature's hydrologic cycle. However, it is a unique natural resource in the sense that the total amount of water available on a global basis is constant, and compared to other renewable resources, like wood or fish, its total stock can neither be increased nor decreased by changing management practices. This, however, does not mean that local or regional resources of water cannot be exhausted by short-sighted use or rendered unusable due to large-scale contamination.

Approximately 71 per cent of the earth's surface is covered with water, and nearly all of this water is saline. Current estimates indicate that the total volume of water on the earth is about 1.4 billion km^3, of which 97.3 per cent is ocean water. The balance, 2.7 per cent, is fresh water. At any given time, 77.2 per cent of fresh water is frozen in the polar ice caps and in glaciers in various parts of the world, and thus, for all practical purposes, is unavailable for human consumption or for vegetation. Ninety per cent of this ice is in Antarctica, and the remainder, for the most part, is contained in the Greenland ice cap. Distribution of the world's water resources is shown below (15):

Location	*Percentage*
Ocean	97.3
Fresh	2.7
Distribution of fresh water:	
Ice cap and glaciers	77.2
Ground water and soil moisture	22.4
Lakes and swamps	0.35
Atmosphere	0.04
Stream channels	0.01

Ground water and soil moisture constitute 22.4 per cent of global fresh water, but nearly two thirds of this lies deeper than 750 m from the ground level. Approximately 0.1 per cent of this reserve (13,000 km^3) participates in the hydrologic cycle in an average year, mostly through contribution to steam flow. Nearly 30 per cent of total stream flow is contributed by ground water. Lakes contain about 200,000 km^3 of fresh water, which is about four times the average annual run-off from all land areas. In contrast, man-made lakes store about 11 per cent of the yearly run-off (about 5000 km^3). Lakes, the atmosphere and streams contain only 0.4 per cent of fresh water, or 0.01 per cent of the total volume of water. This tiny fraction is vitally important in sustaining life on this planet.

The tremendously dynamic nature of the hydrologic cycle can be demonstrated by two simple facts. First, even though the mean annual precipitation of the earth is about 973 mm, the water content of the atmosphere at any given instant is only 0.001 per cent of the total water of the earth, and if by some means all this vapour could be precipitated, it would cover the earth's surface by only about 25 mm. Secondly, not-

* By Asit K. Biswas, International Institute for Applied Systems Analysis, Laxenburg, Austria; Biswas and Associates, Ottawa, Canada; President International Society for Ecological Modelling, Copenhagen, Denmark; and Vice President, International Water Resources Association, Washington, DC. This paper was reprinted with permission from the copyrighted *Journal of the Water Resources Planning and Management Division*, Proceedings of the American Society of Civil Engineers, vol. 105 No. WR2, September 1979, pp. 205-222.

withstanding large discharges of the major rivers, the amount of water contained in the world's rivers at any instant is relatively small. Thus, the important factor to consider in water resources planning and management is not the actual quantity of water in a channel at any time but rather its flow through the channel over time.

While it is not possible to give precise figures for the world water balance at the present stage of our knowledge, all recent estimates have been relatively consistent, even though different methods were used for the estimates. Table 2 shows such an estimate for the average annual water balances of the world (1). The major uncertainty in such analyses comes from the difficulty of estimating precipitation on and evaporation from the oceans due to lack of observed data.

Such a global picture, however, does not give a correct impression of the tremendous variability of water, both with regard to space and time. Water, in any continent, is not evenly distributed. This can be easily shown by considering any continent. If in table 2, Africa is considered, nearly 50 per cent of its total surface water resources are in one single river basin, that of the Congo. Nearly 75 per cent of its total water resources are in eight major river basins – Congo, Niger, Ogooué (Gabon) Zambezi, Nile, Sanga (Cameroon), Chari-Logone (Lake Chad basin) and Volta. This relative abundance of water in the river basins of the equatorial zone of Africa is in sharp contrast to the total lack of water in the world's largest desert, the Sahara, to the north of the equator, and another major desert, the Kalahari, to the south, with varying degrees of water sufficiency or insufficiency in the intervening areas. The savannah area, between the humid equatorial belt and the deserts in the north and south, is most vulnerable to periodic and severe drought, permitting bare survival for man and livestock. Thus, the development of water resources of Africa is an essential prerequisite for the development of its agricultural and industrial potential, besides being a fundamental necessity to long-term survival of man.

Table 2. Average annual water balance of world

Regions (1)	*Volume, in thousands of cubic kilometers*		
	Precipiation (2)	*Evaporation* (3)	*Run-off* (4)
Africa	20.7	17.3	3.4
Asia	30.7	18.5	12.2
Australia	7.1	4.7	2.4
Europe	6.6	3.8	2.8
North America	15.6	9.7	5.9
Latin America	28.0	16.9	11.1
Antarctica	2.4	0.4	2.0
Total, land areas	111	71	40
Oceans	385	425	–40
Total, world	496	496	0

Source: A. Baumgartner and E. Reichel. *The world water balance*, Munich: R. Oldenbourg Verlag, 1975.

During the late Stone Age, man started growing food by raising livestock and farming. Agricultural communities gradually developed on flat and fertile land adjacent to the river valleys. Since the population was small and water was plentiful, people simply migrated during prolonged droughts until better locations were found. Thus, from the very beginning, water has been treated as a "free" resource, a gift from God, that can be used as desired or squandered on whims. This freewheeling concept, until recent times, did not pose serious large-scale management problems.

The situation started changing with the advent of the Industrial Revolution. Centres of dense population started to develop as workers from agricultural sectors were attracted to run the burgeoning industries. As the industrial cities developed, they attracted more migrants from the rural sectors, which, in turn, attracted more industries, and thus created a somewhat vicious circle. Unfortunately, many industries were often established in close proximity to large watercourses because of the ease with which the waste products could be discharged. In addition to the industrial effluents, cities often discharged their wastes into the rivers without much treatment and thus compounded the problem. The result of such developments was gross water pollution near and around centres of population. In medieval Paris, streets were often like open sewers, but the River Seine was clean and one could see fish swimming. Times have changed. Today, the streets of Paris are clean, but the Seine is murky and grey, and one would indeed be fortunate to see any fish.

The demand for water not only involves consideration of its quantity but also its quality. From a planning and management viewpoint, quantity, without any reference to quality, is a meaningless term. Thus, a certain quality of water that can be used for agricultural purposes, may not be used for industrial activities and vice versa. Quantity and quality, however, are closely related. For example, concentration of a pollutant in a stream is directly proportional to the flow. For a fixed amount of pollutant entering a river, the higher the flow, the better is its water quality and vice versa.

During the last decade, the quality of water has become an increasingly important dimension in the eyes of the public. Increases in industrialization, agricultural development, urbanization and *per capita* income have increased the total demand for water. In addition, especially in developed countries, shorter working hours, and pursuit of a better quality of life, have increased the demand for good quality water for recreation near centres of population. Such diverse developments have given rise to a major dichotomy in the water resources planning process. More and more water is being used for different purposes, which so far have tended to deteriorate the quality of water bodies, and simultaneously there is an increasing demand for good quality water near population centres. The situation is

further compounded by discharges into the environment of new chemicals whose effects on humans are unknown, and increasing discharge of other pollutants whose discharge could be neglected earlier because of their low concentration. Examples of such pollutants are toxic substances like arsenic, cadmium, mercury, PCB and different forms of pesticides, as well as other chemicals that may not be toxic but do produce obnoxious environmental effects, e.g. fertilizers that cause eutrophication.

Water is used for many purposes, chief among which are: domestic, irrigation, hydropower, industrial, navigation, recreation, wildlife habitat, and waste disposal. In addition, water resources management plans often consider flood control and low flow augmentation requirements. The quality and quantity of water required to satisfy each of these demands vary considerably, depending on types of demands, geographical locations, cultural traditions, standard of living, climatic characteristics, and other individual factors.

B. Policy Options for Sectoral Uses

Policy options for major sectoral uses on a global and regional scale will be briefly examined below.

1. *Rural and Urban Water Supply*

From a global perspective, the problem of supplying domestic water demand can be viewed within two extremes. At one extreme are the highly urbanized cites of advanced industrialized countries, where the vast majority of the population have in-house water connexions and sewerage services, backed by adequate infrastructure and institutional arrangements, having access to adequate financing, high-level technology and necessary service personnel. At the other extreme is the rural sector of developing countries, having no service of any kind for either potable water or disposal of excretions. In between these two extremes are the majority of cases, where a certain percentage of the population has access to water supply or sewerage services, or both.

The World Health Organization (WHO) carried out a survey in 1976 on the extent of water supply and sewerage facilities available, at the end of 1975, to developing countries. Based on the survey questionnaire that was returned by 67 developing countries, the following scenario emerges (8). In urban communities, 57 per cent of the population have house connextions and another 18 per cent have access to stand-pipes, making a total of 75 per cent (390 million people) that have access to potable water. The situation, of course, is far worse for the rural sector, where only 20 per cent (248 million) have reasonable access to safe water. Considering both rural and urban populations together, only 35 per cent (638 million) are adequately served.

These, of course, are average figures, and hide the tremendous disparity that exists even within the developing countries. The range of this disparity can be easily seen by considering the community water supply situation in Africa. At the upper range are several countries where more than 90 per cent of the urban population are served by potable water. These are Botswana, Lesotho and Liberia (all 100 per cent); Mauritius and Senegal (98 per cent); Gambia, Guinea, Ivory Coast, Kenya, Togo and Zambia (97 per cent); Benin and Egypt (94 per cent); and Morocco and Tunisia (91 per cent). At the bottom end of the scale are the rural populations of many countries, where even 5 per cent do not have access to safe water. These are Burundi, Gabon, Madagascar, and Sierra Leone (1 per cent or less); Gambia, Kenya, Togo and Zaire (5 per cent or less). In addition, there are several other countries where data on rural sectors are not available, but they are virtually certain to be less than 5 per cent. These are the Central African Republic, Ethiopia, Guinea, and Lesotho (14).

The goal of the Second International Development Decade of the United Nations is to extend water availability by 1980 to 100 per cent of urban populations (60 per cent through house connexions and 40 per cent through stand-pipes), and 25 per cent of rural populations. The investment required to reach this goal for Africa has been estimated at $US3.5 billion, $2.6 billion for urban and $0.9 billion for rural populations (17), which this writer estimates to be a conservative figure.

Unless a concerted effort is made to meet the targets, these will continue to remain targets. This is especially true in view of the latest unencouraging picture of Africa that has emerged from the WHO survey (8):

> "The percentage of the urban population served by house connexions in Africa increased only marginally from 33 per cent to 36 per cent from 1970 to 1975. Therefore, a more realistic target of 45 per cent to be achieved by 1980 is now proposed for this region, instead of the global target of 60 per cent already adopted. The percentage of the urban population served by public standposts has actually decreased from 34 per cent to 29 per cent. The proposed new target is 35 per cent, giving a total 1980 urban target of 80 per cent, including both house connexions and public standposts.
>
> In the rural sector, the percentage of the population having reasonable access to safe water increased from 13 per cent in 1970 to 21 per cent in 1975. In view of the progress made, a new target of 35 per cent is proposed for attainment by 1980".

If the targets are met for Africa by 1980, and this target is continued to the year 2000, the number of people without safe water will continue to increase with

time. As shown in table 3, it is estimated that during the period 1970 to 2000, populations served with safe water will increase from 92 million to 433.5 million, but during the same period, the number of people not served will increase from 188.6 million to 379.5 million. This means that unless the countries and the international community revise the targets upwards after 1980, not all the population of Africa will have access to safe water even by the year 2000 (14).

The quality of water available is of prime importance to human health. Use of potable water will undoubtedly reduce health hazards like cholera, typhoid, infectious hepatitis and bacillary dysentery. It would further reduce human contacts with sectors of water-borne diseases like schistosomiasis, trypanosomiasis or guinea worm (*Dracunculus Medinensis*). Schistosomiasis will be considered later. With regard to trypanosomiasis, some have estimated that the Gambian sleeping sickness, *Trypanosoma gambiense*, can be reduced by 80 per cent through good water supply schemes (7). While this figure may be somewhat optimistic, there is no doubt that the provision of potable water will reduce the incidence of the dreaded sleeping sickness disease by reducing the exposure of human beings to tsetse flies during the water collection journey. Similarly, guinea worm infection, which currently affects some 48 million people, chiefly in India and west Africa (12), can also be reduced. Maximum infection occurs during dry periods, when people rely on ponds and other shallow sources. Infection rates of over 50 per cent have been observed in India and Nigeria, and incidences of around 20-30 per cent are commonly reported (10). The health and economic costs to the communities can be substantially reduced by rational water resources development and management. It would further reduce the water collection journey, mainly of women and children who currently spend up to five hours every day collecting the family water requirements (19). The time, thus freed, can be used for learning or productive work.

2. *Water for Agriculture*

Water is essential for agriculture, and if the world food crisis is to be solved, there is no alternative but to increase the total area under irrigation. The potential benefits to crop production under various degrees of water control, combined with additional material inputs and consistent with cultural practices, are shown in table 4 (18) which shows that average output increases with increases in the degree of over-all control.

Cropping intensity is a key element in determining the value of irrigation and benefits to be accrued from such developments. These indices are especially important where arable land is scarce, and thus limits to agricultural production will be determined by crop yield and intensity of cropping. Table 5 shows irrigated areas and cropping intensities for developing market economy countries for 1965 and 1975, and projected values for 1990 (18). The cropping intensity for 1975 ranged from 89 in Latin America to 129 for Asia, and the 1975 values for all four regions are higher than the corresponding figures for 1965.

Agriculture is the largest user of water, and accounts for some 80 per cent of global consumption (the comparable figure for the United States is slightly over 40 per cent). In 1975, the total area irrigated in the world amounted to 223 million ha, of which 92 million ha were in developing countries. By 1990 it is estimated that these figures will have risen to 273 million ha, and 119 million ha, respectively (18).

It is however not enough to increase irrigated areas. Effectiveness and efficiency of the supply and distribution system must be maintained. Current estimates indicate that some 86 million ha throughout the world are now in need of improvement. Similar improvement will be necessary on 45 million ha in the developing market economy countries mentioned in table 5, out of a total of 92 million ha, by 1990. The estimated cost for such improvement, at 1975 prices, will be more than $US 22.5 billion. In addition, adequate drainage improvement work has to be carried out on 52.4 million ha (much of it within the 45 million ha of irrigation improvement) at an additional cost of $US 12.4 billion for the proper control of water and salt balance in the soil. Thus, the total cost of irrigation improvement schemes for the developing market economy countries, up to the year 1990, is expected to be $US 34.9 billion.

As it will be more difficult and expensive to develop land and water resources in the future than it was in the past, the cost for new irrigated land (22.2 million ha) for the same countries mentioned earlier is expected to be over $61 billion (at 1975 prices), giving an approximate average price of $2800/ha. Provision of adequate drainage is included in the estimate, ranging from $200 to $1000 per ha. The recent experience of escalating costs by the World Bank, however, does not bode well for the world. Costs of the magnitude of $5000 to $6000 per ha, for exclusively gravity irrigation systems, are not now uncommon. Thus, if anything, the latest estimates may be somewhat on the conservative side.

The enormity of the task of expanding and maintaining irrigated areas in the developing market economy countries up to the year 1990 is, in itself, staggering. Its magnitude can be seen from the following summary: (1) 22.2 million ha of new irrigation; (2) 45 million ha of irrigation improvement; (3) 78.2 million ha of drainage improvement, including 52.4 million ha on irrigated land; (4) 440 billion m^3 of additional water; and (5) $96 billion of investment at 1975 prices.

These investment costs, it must be realized, do not include costs of new irrigation or improvement of existing irrigation systems outside developing market

Table 3. Water supply situation in Africa, 1970-2000

Population (1)	1970			1980			2000		
	Total (2)	Served (3)	Not served (4)	Total (5)	Served (6)	Not served (7)	Total (8)	Served (9)	Not served (10)
Urban	70.0	51.2	18.8	108.0	108.0	0	307	307	0
Rural	210.6	40.8	169.8	289.0	72.3	216.7	506.0	126.5	379.5
Total	280.6	92.0	188.6	397.0	180.3	216.7	813.0	433.5	379.5

Note: Population is in millions, and does not include Angola, Equatorial Guinea, Malawi, Mozambique, Namibia, Rwanda, South Africa, Rhodesia, Swaziland, and island countries and territories.

Table 4. Yields of paddy rice with different degrees of water control

Degrees of water control (1)	Material inputs (2)	Location (3)	Average yield for 1971-1974, in tons per hectare (4)
No water control (rainfed, uncontrolled flooding)	nil	Lao People's Democratic Republic	1.3
Successive introduction of water control			
Elimination of floods	nil	Democratic Kampuchea	1.5
Elimination of drought	low fertilizer application	Burma India Thailand	2.0
Improved water control (irrigation and drainage)	low to medium fertilizer application	Pakistan Viet Nam Republic Sri Lanka Malaysia, West	3.0
Sophisticated management practices (mid season-drying)	high fertilizer use + improved seeds and pest control + diversification mechanization	Republic of Korea Japan	5.0 6.0
Experimental conditions			10.0

Source: Water for Agriculture, Water Development and Management, vol 3, FAO, Oxford, Pergamon Press, 1978.

Table 5. Irrigated Land (IL in thousands of hectares) and Cropping Intensities (CI in percentage utilization of Cultivated Area) for Developing Countries, 1965-1990

Region (1)	1965		1975		1990	
	IL (2)	CI (3)	IL (4)	CI (5)	IL (6)	CI (7)
Africa	1,882	104	2,610	107	3,570	121
Latin America	9,623	77	11,749	89	14,850	95
Middle East	13,329	80	17,105	95	21,400	106
Asia	45,691	119	60,552	129	74,370	142

Source: Same as table 4.

Table 6. Water requirements and waste loads for selected industries

Industry (1)	Unit (2)	Range of water requirements per unit of product (3)	Pounds of 5-day BOD per 1,000 gal of process water discharge (United States) (4)
Steel	Ton	8,000-61,000	-
Soap	Ton	960-37,000	16.70
Gasoline	Kiloliter	7,000-34,000	2.50
Paperboard	Ton	62,000-376,000	2.21
Sugar beets	Ton	1,800-20,000	9.16

Source: "Resources and needs: Assessment of the World Water Situation", United Nations Water Conference: Summary and Main Documents, edited by Asit K. Biswas, Oxford, Pergamon Press, 1978.

Table 7. Potential and current hydropower developments of different continents

Continent (1)	Potential available 95% of time (thousands of kilowatts) (2)	Potential Output 95% of time (millions of kilowatt-hours per year) (3)	Present installed capacity (thousands of kilowatts) (4)	Current annual production (millions of kilowatt-hours per year) (5)	4/(2) x 100 (6)
Africa	145,218	1,161,741	8,154	30,168	2.6
Asia	139,288	1,114,305	47,118	198,433	17.8
Europe (including USSR)	102,961	827,676	135,498	505,317	61.0
North America	72,135	577,086	90,210	453,334	78.5
Latin America	81,221	649,763	18,773	91,415	14.1
Oceania	553,810	4,434,468	307,362	1,307,564	29.5

Source: Same as table 6.

economy countries. It is estimated that, by 1990, for the rest of the world, new irrigation will have been provided for 23.1 million ha, 41.3 million ha of existing irrigation will have been improved, and all these developments will require an additional 528.4 billion m^3 of water. The investment cost for this additional part is not available at present.

3. *Water for Industry*

Industry requires a large amount of water. In the United States industrial demand accounts for nearly 40 per cent of the total water requirement, and five major industrial groups – food and kindred products, pulp and paper, chemicals, petroleum, coal products and primary metals – account for slightly more than 85 per cent of total withdrawals. Approximately 60 to 80 per cent of the water required for industrial processing is for cooling, and need not be of high quality. However, such an enormous discharge of heated water has intensified the problem of thermal pollution, and some studies indicate that the quantity of heat to be dissipated to the aquatic environment will have increased ten-fold in the United States during the last three decades of this century (3). The possibility of using thermal discharges for beneficial purposes is not very significant at the present time (5).

There are basically two sets of policy issues with regard to industrial use of water: (1) use of river systems to dispose of industrial wastes; and (2) the striking difference between the gross amount of water needed for various industrial processes to manufacture the same product. Besides discharging heated water, industry is responsible for the disposal of a whole variety of waste products, depending on the stringency of local pollution control measures. Thus, discharges of mercury to the aquatic environment have created serious problems in Japan and Canada, with the resulting development of the Minimata disease. Similar problems have been observed with cadmium, arsenic and PCB, as a result of which new rules and regulations are being drafted and updated in different parts of the world.

The second set of policy issues is on the actual use of water by industry. The amount of water required depends on the type of industry, processes being used, availability of water, and legal requirements. The cost of water is rarely a major issue, since it represents 0.005 to 2.58 per cent of total manufacturing costs for the five most intensive water-using industries mentioned earlier, Seldom does this cost exceed 1 per cent. Within these limits, water requirements vary tremendously for the same industrial group, as shown in table 6 (15). It is quite common to find some industrial plants requiring 5 to 40 times more water than other plants manufacturing the same product. The example of soap, given in table 6, indicates the higher range to be 38 times that of the lower. Such drastic differences in net amounts of water required are due to the use of extensive in-plant recirculation and treatment technologies, as compared to simple once-through flow processes. While the water requirement for industrial purposes is high, a small fraction of the water used is actually "consumed", i.e., incorported into the product, or lost through evaporation or seepage.

According to the targets of the Second International Development Decade, industry in developing countries is expected to grow at an annual average of 8 per cent. The Lima Declaration and Plan of Action envisages that their total share of manufacturing output will increase to 25 per cent by the year 2000. If these targets are met, industrial water requirements for developing countries will increase substantially. Effects of such manifold increases of industrial activities on water will depend on availability of supply and, more importantly, on the standards set by the various administrative bodies on the quality of receiving waters.

4. *Hydroelectric Power*

Hydroelectric power is an important product of water development, and currently accounts for 70-90 per cent of all electricity generated in Brazil, Canada, Morocco and Norway. With the current energy situation, hydroelectric power makes a great deal of sense in many countries, especially in terms of achieving self-reliance and reducing balance of payments problems due to the importation of energy-producing materials. While capital costs for hydropower developments are quite high, the running costs are minimal. In addition, such developments, if properly planned, could be highly labour-intensive and thus reduce unemployment problems in developing countries.

The potential for hydropower has been exploited to a great extent in North America and Europe, including the Soviet Union, as shown in table 7 (15). However, there is a vast potential that can be exploited in Africa, Asia, and Latin America. Africa is the most underdeveloped, the current annual production being only 2.6 per cent of the potential output. In sharp contrast to North America, where the share of hydropower in total electricity generated has been steadily declining, and is expected to continue to decline in the future, the situation in Africa – even with the current very low level of development – has been quite the opposite. Thus, the share of hydropower has increased from 22.9 per cent in 1962 to 28.4 per cent in 1974. This trend towards increased emphasis on hydropower generation, in preference to other forms of energy development, is expected to continue in the foreseeable future.

There is a major misconception with regard to hydropower. Many people tend to think that because of economies of scale, all recent developments must be large-scale, such as the Aswan in Egypt, the Volta in Ghana, or James Bay in Canada. The global situation is somewhat different, however. It is the small and medium-sized potentials that offer the greatest promise in the future.

C. Social and Environment Impacts of Water Development

All water resources development projects have social and environmental implications. Whether such implications are acceptable depend very much on individuals concerned, their personal interests, views and biases. It is quite common to find that a new development project is unacceptable to a certain segment of society, while another segment lobbies hard for its implementation.

The social and environmental implications of water development are many, and the resulting effects often extend much further than the river basin unit itself. The interactions of diverse forces are often so complex that ecologists and environmentalists are hard-pressed to predict over-all effects with any degree of certainty. At the present state of the art, ecologists often find it impossible to convince engineers, economists, and politicians that certain developments are unwise, or of the necessity to spend scarce resources on appropriate remedial measures becase of the lack of hard facts or solid scientific evidence. In addition, water resources development has been traditionally within the domain of engineers and, consequently, social and environmental considerations have often been neglected during the planning process. A typical example is the near disaster in the Peace-Athabasca Delta in Canada, due to the construction of the Bennett Dam. Consistent reduction of the level of the lake played havoc with the local flora and fauna, which seriously affected the life-style of the local Treaty Indians and Metis. The social dislocation was quite serious, and the situation was finally rectified at significant economic cost.

The social and environmental impacts of water development can best be considered by dividing the effects into three categories of subsystems: physical, biological and human.

1. *Physical Subsystem*

Development projects invariably change river and ecosystem regimes, and thus the real question is not whether a dam will affect the environment, but how much change is acceptable to society as a whole, and what countermeasures should be taken to keep the adverse changes to a minimum and within that acceptable range. The Aswan dam in Egypt, one of the major dams of the world, has received its share of criticism for contributing to environmental disruptions. The scheme, built primarily for generating hydropower, has reduced the fish population of the Mediterranean by abruptly breaking the aquatic food chain in the Eastern Mediterranean. Planktons and organic carbons have been reduced by about two thirds because of the lack of the Nile sediments, which are now trapped in the reservoir created by the dam. It has, in turn, substantially reduced the sardine, scombroid, and crustacean populations of the area. Erosion has become a major problem, and the fertility of the Nile valley has been lowered by the lack of sediments. Already a proportion of Egypt's 2.4 million ha of cultivated land needs artificial fertilizer, and it is anticipated that the rest will need it in the near future (2). Salinity in Middle and Upper Egypt is increasing rapidly, and some agronomists have predicted that it will be a very expensive process to rectify the situation. This, however, does not mean that the Aswan dam should never have been built, since it is absolutely essential for Egypt's economic development. Rather it means that secondary and tertiary effects should have been foreseen to the extent possible, and appropriate measures should have been taken during the planning phase to reduce them to an absolute minimum.

Water development projects to increase irrigated agriculture have also contributed to problems that eventually reduced total food production. Among such problems are deterioration of soil fertility and eventual loss of good agricultural land, due to progressive development of salinity or alkalinity. At one time Pakistan alone was losing 24,280 ha of fertile cropland every year, and currently, nearly 10 per cent of the total Peruvian agriculture is affected by land degradation due to salinization (6). Among other major areas affected by salinization are Helmud Valley in Afghanistan, the Punjab and Indus Valleys on the south Asian subcontinent, Mexcali Valley in northern Mexico, Imperial Valley in California, and the Euphrates and Tigris basins in the Syrian Arab Republic and Iraq. A study of major modern irrigation schemes in the Punjab shows that seepage from unlined canals has, in the first 10 years of operation, raised the water table 7 to 9 m above the long-term levels recorded since 1835 (13).

On a global scale approximately 20 million km^2 of soil has been destroyed or degraded, which is nearly 35 per cent more than the 14 to 15 million km^2 of arable land currently being used for agriculture (16). Currently 46 per cent of the earth's surface affected by degradation hazards can be directly related to water. These hazards can be roughly estimated as follows: (1) water erosion, 22 per cent; (2) waterlogging and flood damage, 8 per cent; (3) salinity and alkalinity, 5 per cent; and (4) frost, 11 per cent.

The possibility of inducing earthquakes by construction of large dams is another environmental problem that has not received adequate attention so far. The 1967 Koyna dam disaster in the Indian peninsula, which resulted in a heavy loss of lives and considerable property damage, was due to an earthquake whose epicentre coincided with the dam itself. In general, the seismic disturbances can be traced to the existence of inactive faults and it seems likely that the effect of the added forces contributed by the dam and reservoir liberate orogenic tensions of much greater strength.

2. *Biological Subsystem*

One of the most serious impacts of irrigation developments in the tropical and semitropical regions is the secondary effect of spreading water-borne diseases, and the consequent suffering of millions of human beings and animals. Irrigation schemes have often enhanced and created favourable ecological environments for parasitic and water-borne diseases such as schistosomiasis, liver fluke infections, filariasis, and malaria to flourish. These diseases are not new; e.g., schistosomiasis was known during Pharaonic times. But unprecedented expansion of perennial irrigation systems ha introduced such diseases into previously uncontaminated areas.

Such developments have been conclusively demonstrated in several countries of the world. In Egypt, the replacement of simply primitive irrigation with perennial irrigation has caused a high incidence of both *S. mansoni* and *S. haematobium;* where basin irrigation is still practiced, the incidence is much less. Infection rates in four selected areas, within three years of the introduction of perennial irrigation, rose from 10 to 44 per cent, 7 to 50 per cent, 11 to 64 per cent and 2 to 75 per cent. The life expectancy of males and females in heavily infected areas is estimated to be 27 and 25 years, respectively. In Sudan, with the introduction of perennial irrigation to 360,000 ha under the Gezira Scheme, the incidence of blood fluke rose greatly. It also increased the incidence of flukes in cattle and sheep. In Kenya, Lake Victoria is hyperendemic for schistosomiasis. *S. mansoni* infection in school children is up to 100 per cent in areas associated with irrigation schemes. In Transvaal, South Africa, the *S. mansoni* infection rate on European farms was 68.5 per cent compared with only 33.5 per cent in the reserves, because the former had irrigation. Similarly, in some countries in Asia and the Pacific, irrigation has not only increased schistosomiasis, but also liver fluke infections, eosinophilic meningitis, and bancroft filariasis.

3. *Human Subsystem*

Naturally all the effects mentioned earlier have direct impacts on human beings, but the distinction could be made that such developments at first contribute to environmental and ecological changes, which, in turn, affect the human subsystem. Under the present subheading, only the direct impacts will be considered.

Many of the large dams have contributed to the displacement of local inhabitants, which in certain cases has resulted in serious problems. Thus, the Kariba dam on the Zambesi displaced approximately 57,000 Tonga tribesmen, who had to pay a great price for this progress. What the planners, often from outside Africa, did not realize was the enormously complex relationship between the African tribes and their land. The resettlement programme for the Tonga tribesmen left much to be desired; not only did they suffer great cultural shocks when thrust into communities as different from their own as theirs are from the United Kingdom, but also it took two years to clear sufficient land to meet their subsistence needs. The Government had to step in to avert famine and very serious hardships and, ironically, this good-intentioned step was probably the most destructive. The food distribution centres also became transmission sites for the dreaded sleeping sickness disease.

This, however, has not been a unique occurrence. Approximately 100,000 people had to be relocated for the Aswan High dam without adequate planning, and the World Food Programme had to rush in famine relief for the Nubians. Similarly 80,000 people had to be related because of the Volta dam in Ghana, and the World Food Programme had to step in again to avoid a major catastrophe (4).

D. Politics of Water

Politics and water are closely interconnected. Invariably the final decision to develop a water resources scheme is very much a part of the political process. The planners and experts do not make the final decision, nor do they pass legislative actions that directly or indirectly affect the planning process. They do, however, where possible, point out the cost-effectiveness of the various alternative courses of action, and this information helps the decision-makers arrive at responsible decisions. Thus, the real decision-making lies with the politicians. In fact, water resources planning, project authorization, and level of funding are all essentially political processes. Thus, the planners decide the feasibility of the project, and politics decides the implementation of the plan. It can be argued that, irrespective of the technical feasibility, economic profitability, and social desirability of a project, it can happen only if effective political leaders can champion its cause in the right way at the right time.

There are other important political dimensions of water management. In countries like the United States, Canada, the Federal Republic of Germany, or India, there is a continuing scope for conflict between the two levels of government – federal and provincial. For example, in Canada, water is under the provincial jurisdiction (except for international waters), but the Federal Government maintains a strong interest in the area. Parts of the Canada Water Act have never been implemented because of the thorny question of jurisdiction over water. Many of the Canadian pollution control regulations are based on the fact that fishing is under Federal jurisdiction, and accordingly harmful discharges that affect fish can be controlled or prohibited by Federal regulations.

Conflicts between neighbouring states over water resources development projects occur quite frequently in India. The most common unit for water development plans has been the river basins, many of which fall in

two or more adjacent states. Ideally, it would be desirable to develop an optimum water utilization plan for a specific river basin, and then let the states share the profits and costs, on some equitable basis. This has seldom worked. Distrust and suspicion between states, determination by one or two to get more than their fair share of the benefits for less than their fair share of the costs, and long-standing hostilities over other issues, seriously complicate the negotiation process to develop mutually advantageious plans. The question of language further complicates the issue, since very few neighbouring states in India have the same common language. In addition, because of the mutual distrust, available and complete technical, economic, and social information is very seldom willingly shared. Thus, it is quite common to find that both states are collecting the same information separately, and carrying out individual assessments. Nor is it uncommon to find long and protracted negotiations between states, often hostile, with no agreement being reached at the end. This often necessitates setting up a tribunal at great expense; all these events not only delay the development process up to anywhere in the region of 10 years, but also ensure the evolution of suboptimum plans.

While the problem of resolution of interstate conflicts within a country is not satisfactory, the situation is far worse for international river basins. At least there are some infrastructural arrangements and precedents to solve interstate conflicts in a country, but these are virtually non-existent in dealing with international problems. One recent report (11) concludes that:

> International river issues often entail conflict between public international morality, as expressed by international law, and Basin State self-interest. There are few sanctions to apply against those countries which disregard internationally accepted rules of behaviour and accepted principles of sharing, except the disapproval of the international community.

Because of such a sad state of affairs it is not surprising to find that major conflicts have developed between several countries in recent years, which have severely strained their mutual relationships. Many such conflicts are yet to be solved. Typical examples of such current conflicts over shared water resources are between India and Bangladesh, Iraq and the Syrian Arab Republic, and Brazil and Argentina. As more and more water is required by all countries for further development of urban, rural, agricultural, industrial and other sectors, such conflicts between countries over shared water resources will continue to increase, at least for the next decade.

This poses a major question: will enough water be available for future developments in the world? Some people have already suggested that water, rather than land, could be the major constraint for increasing world food production during the final years of this century, but this is difficult to justify at present.

Several studies are now available that assess the world water situation on regional and global bases up to the year 2000, and one to the year 2060 (9). While specific figures vary somewhat, general conclusions are remarkably similar, and can be summarized as follows:

		1973	*2000*
1.	Estimated population (million)	3 860	6 500
2.	Potentially available water per person per year (m^3)	10 400	6 200
3.	Prospective demand per person per year (m^3)	1 000	1 000
4.	Ratio of 2:3	10	6

This indicates that even without extensive conservation and recycling processes, only one sixth of the potentially available water will be used by the year 2000. It should be pointed out that minimum water requirements, according to the WHO estimate, are 150 l/person/day for sanitary reasons, which works out to be 54 m^3/person/year. The figure of 1000 m^3 of water use per person per year includes a much higher water use than recommended by WHO, and water required for other sectoral uses.

What then is the problem of water availability in the future? It is basically a problem of rational management. Water resources of different regions, on which adequate data are not available, have to be assessed and, based on such assessments, long-term development and management plans have to be established. Water and land should not appear as constraints in the over-all planning process of a country; rather, realistic development and production targets should be matched as to their availability.

If the current trends continue, water problems will appear in certain regions of the world. This, however, need not be the case, since such shortages can be significantly alleviated by more efficient use of water. More emphasis has to be placed on demand management rather than on supply management, as has generally been the case so far. The concept of supply management, which considers an increase in supply as virtually the only management choice, will gradually disappear – except perhaps for a few areas exceptionally well-endowed with water resources or experiencing a relatively low level of demand.

There is considerable scope for improving the efficiency of water use in virtually every country and in every sector. The agricultural sector, which accounts for nearly 80 per cent of global water consumption, is probably the most inefficient sector, and thus the one

in which most improvements could be made. Existing efficiencies of irrigation systems are often so low that they do not by any means reflect the real water requirements for crop production. In fact, in many instances present water consumption patterns are not only wasteful but are also definitely harmful. From some recent studies of several developing countries, it is quite common to find that 80-85 per cent of water delivered to the head gate of the main canal never reaches the crop. Thus, projection of future global water requirements based on present day "demands" is highly misleading and the time has come to ask whether such analyses have any technical value. Water consumption per unit area has been decreasing slowly during the recent past, but it must be admitted that it is still far from the real value.

Despite these advantages, one may legitimately ask why has the rehabilitation of existing schemes not received the priority it deserves? The answer is complex but, at the risk of simplification, the following explanation is offered. An analysis of past priorities and the actions taken in many countries indicate that agriculture (and thus irrigation) has not received the importance it deserves. Many large new dams have been built with the main objective of providing cheap power for rapid industrialization of the country; irrigation development, and especially improvement, took a back seat. Also, several developing countries, at least in the past, opted for prestigious projects such as large dams, football stadiums, nuclear power plants, or airports, rather than putting through critically necessary land reforms or irrigation improvement. The reason for such a course of action is not difficult to discern. A brand new large structure has prestige; politicians can make political hay out of it. Such projects have also served the donor countries well, both in terms of propaganda value and opportunist motives; they seem to be often more interested in financing large and visible structural projects, irrespective of their immediate relevance to the recipient country's national needs. Such attitudes seem to be changing, but progress is slow.

Efficiency of water use can also be significantly improved in industrial and domestic sectors. In some countries, such as Canada, where industry claims nearly 84 per cent of total withdrawal (the comparative figure for India is 1 per cent), extensive recycling and process changes, especially for new industry, will bring water requirements towards the lower range of the values shown in table 6. Use of existing knowledge, supported by more rational water pricing structures, can reduce these values even further.

There is considerable scope for water conservation in the domestic water supply sector as well. In developed countries, the original principle objectives of potable water supply, drinking and washing, have long been relegated to secondary roles in terms of the quantity of water used. The major uses are now for lawn watering (which may account for 50 per cent of water used in middle and upper income neighbourhoods), washing machines, dish washers and car washing. Extremely high levels of loss in the distribution systems, especially in the developing countries, is a major problem. In certain urban areas such leakage losses could account of half of the total water pumped. For a city like Calcutta, that has an acute water shortage problem, no one really knows how much potable water is lost due to such leakages. Further problems are created due to lack of service personnel and proper maintenance practices. Thus, 70 per cent of hand pumps installed are out of order in many parts of the world, and constantly running standpipes are now quite common sights in many rural and urban centres of the developing world.

To sum up, the major problem in the area of water resources is not one of the Malthusian spectre of impending scarcity, but one of instituting more rational and better management practices. What is urgently needed is the formulation of long-term policies that reflect changing water demand patterns consistent with efficient use, and better appreciation of the social and environmental effects, with a view to minimizing the adverse impacts. In fact, one can argue that the time has come when the emphasis should shift to comprehensive land and water planning, treating land and water as an integrated and interacting unit, rather than water planning *per se*.

Bibliography

1. Baumgartner, A. and Reichel, E. The world water balance. Munich, R. Oldenbourg Verlag, 1975.

2. Biswas, A.K. Sociological aspects of water development. *Water Resources Bulletin*, 7:6:1137-1143, December 1971.

3. Biswas, A.K. Non-radiological environmental implications of nuclear energy. Background paper for International Panel of Experts Meeting on Nuclear Energy and the Environment, Geneva, Switzerland, 20-24 November 1978. Nairobi, United Nations Environment Programme.

4. Biswas, A.K. and Biswas, M.R. Hydro power and the environment. *Water Power and Dam Construction*, 28:5:40-43, May 1976.

5. Biswas, A.K. and Cook, B. Beneficial uses of thermal discharges. Report No. 2, Planning and Finance Service. Ottawa, Department of Environment, 1974.

6. Biswas, M.R. Environment and food production. *Food, climate and man*, edited by M.R. Biswas and A.K. Biswas. New York, John Wiley and Sons, Inc., 1979, pp. 125-158.

7. Bradley, D.J. Water supplies: The consequences of change. *Human rights in health.* CIBA Foundation Symposium No. 23. Amsterdam, Associated Scientific Publishers, 1974, pp, 81-98.

8. Community water supply and waste-water disposal. Mid-decade progress report. Twenty-ninth World Health Assembly, Document No. A29/12/Rev. 1, Geneva, 1976, pp. 9-10.

9. De Maré, L. Resources-needs-problems, Report No. 2, Lund, Lund Institute of Technology, 1976.

10. Feacham, R. The rational allocation of water resources for the domestic needs of rural communities of developing countries. Proceedings, Second Congress of the International Water Resources Association. New Delhi, December 1975, pp. 539-546.

11. Fox, I.K. and Le Marquand, D.G. International river basin co-operation: the lessons of experience. *Water Supply and Management,* 3:1:9-28, January-February 1979.

12. Müller, R. Dracunculus and dracunculiasis. *Advances in parasitology,* Vol. 9, edited by B. Dawes. New York, Academic Press, 1971, pp. 51-73.

13. Pereira, H.C. Land use and water resources. London, Cambridge University Press, 1973.

14. Problem of water resources development in Africa. *Water Development and Management,* vol. 2, United Nations Economic Commission for Africa. Oxford, Pergamon Press, 1978, pp. 519-637.

15. Resources and needs: assessment of the world water situation. United Nations Water Conference: Summary and Main Documents, edited by Asit K. Biswas, United Nations Water Conference Secretariat. Oxford, Pergamon Press, 1978, pp. 25-69.

16. State of the Environment. Nairobi, United Nations Environment Programme, 1977.

17. Village water supply. Washington, DC, World Bank, pp. 24-28.

18. Water for agriculture. *Water development and management,* vol. 3, Food and Agricultural Organization of the United Nations (FAO). Oxford, Pergamon Press, 1978, pp. 907-941.

19. White, G.F., Bradley, D.J. and Emurwon. Drawers of water: domestic water use in Africa. Chicago, University of Chicago Press, 1972.

Subject	*Source*	*Description*
Conservation in agriculture	J.G. Pike and A.K. Mitra, "A multi-disciplinary approach to the reclamation of irrigation schemes in central Iraq", *Journal of the Institution of Water Engineers and Scientists*, vol. 31, No. 3, pp. 175-186, May 1977.	Iraq needs to improve agricultural production to feed a growing population. Land deterioration in the central alluvial plain necessitates carefully planned large-scale reclamation schemes, calling for an integrated multi-disciplinary approach to investigate problems imposed by the existing irrigation and farming system and by the adverse natural conditions, all of which limit the choice of alternatives and options. Discussed herein are: (1) irrigation in Central Iraq; (2) the Greater Mussayib Project, its topography, soils, climate, water resources, irrigation and drainage system, and irrigated farming systems; (3) project investigations, including objectives, a farm management survey, and optimum farming systems and cropping patterns by linear programming; (4) development proposals, considering irrigation and drainage, farm development and infrastructure; and (5) investment feasibility. It is concluded that project studies need to assess the existing farming system's resources and ability to bring about changes. The core of the investigation is to mount a farm management survey at an early stage, from which technical data, farming systems, and benefit-maximized cropping patterns and water requirements may be determined. This would yield criteria for redesigning the irrigation and drainage network, infrastructure and institutions.
Conservation in agriculture	F.D. Whisler, and H.F. Hodges, "Conserving supplemental irrigation water applied to soybeans", Available from the National Technical Information Service, Springfield, VA 22161 as PB80-119936.	In order to conserve or use most wisely agricultural water supplies as supplemental irrigation to natural rainfall, knowledge of when to irrigate, how much to irrigate and what are the plants' responses to water stress are needed. Studies to answer parts or all of these questions for soybeans were conducted in 1978 and 1979 at the Blackbelt Experiment Stations near Brooksville, Mississippi and at the Plant Science Farm at Starkville, Mississippi. Field plots at the Blackbelt Station were covered with plastic with trickle irrigation beneath the plastic to control the soil moisture on some of the stressed plots. Large (76 litre) containers were used at the Plant Science Farm to control a high water table condition. Plastic covers and irrigation beneath the plastic was used on some containers to induce stress when desired. The plants' most critical period of water requirement was during the pod filling stage. The amount of water needed as supplemental irrigation varied with the year and location. The water usage during pod filling was two to eight times more in a dry year like 1978 than in a wet year like 1979. Stressed plants tended to close their stomata and thereby increase their leaf diffusive resistance. This reduced their sensitivity to environmental variables and evaporative demands. Non-stressed plants were much more sensitive to environmental variables such as soil water content and solar radiation.
Control of water on the surface	E.S.Salvo, "Slow sand filters for the Leyte Metropolitan Water District", *Water pollution*	The Leyte Metropolitan Water District in the Philippines comprises the city of Tacloban and the municipalities of Palo, Tanauan, Pastrana and Dagami. The

Subject	*Source*	*Description*
	control in developing countries. Proceedings of the International Conference held at Bangkok, Thailand, February 1978. Edited by E.A.R. Ouano, B.N. Lohani and N.C. Thanh, Asian Institute of Technology, Bangkok (Pergamon Press in United States), pp. 415-420, 1978.	most advantageous source of water is located high up in the mountains but because of the high cost of transportation to the site, a new source on the same river was selected. The new source is lower in elevation by 85 metres but substantially inhabited. An infiltration gallery utilizing the principles of slow sand filters was designed. Two layers of sand and well-graded gravel formed the filter media. Slotted polyvinyl chloride (PVC) pipes formed the underdrains.
Control of water on the surface	S.G. Walesh, "Flood insurance programme: Regional agency's perspective", *Journal of the Water Resources Planning and Management Division,* Proceedings of the American Society of Civil Engineers, vol. 105, No. WR2, September 1979, pp. 243-257.	While the National Flood Insurance Programme (NFIP) in the United States has enhanced flood plain management on the national level, some aspects of the programme have frustrated flood plain management efforts within state and local governmental jurisdiction. Positive features of NFIP as seen from the perspective of a regional planning agency experienced in flood plain management are: mandatory flood plain regulations and certainty of post-flood financial assistance. Negative features of NFIP are: problems associated with the required floodway delineations, the civil division orientation, use of existing condition flood hazard data for regulatory purposes, and the limited scope with respect to finding solutions to existing and future flood problems. The effectiveness of NFIP could be enhanced by: conducting studies on a watershed basis, encouraging comprehensive land use planning and control in riverine areas, analysing upstream and downstream impacts of floodways, determining the impact of future land uses, and encouraging the use of flood insurance studies as the first phase of comprehensive watershed studies.
Effects of pollution	D.A. Henley, "An investigation of proposed effluent discharge into a tropical mangrove estuary", *Water pollution control in developing countries.* Proceedings of the international conference at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 43-64, 1978.	Described are environmental studies carried out to determine the likely effects of effluent discharge into a mangrove-fringed estuary at Darwin in northern Australia. The oceanographic studies are described together with the statistical method used to calculate likely buildup of pollutants within the estuary. Studies of the nutrient status of the mangroves, including their sediments, are also described. They were used to assist in determining likely effects on the mangroves of an increase in nutrient. It was concluded that effluent from a primary-secondary lagoon system could safely be discharged within the mangrove areas with no detrimental effect.
Evaluation process	S.M.H. Bokhari, "Case study of the demand/supply relationship for the Indus River Basin", *Water Supply and Management,* vol. 3, No. 3, pp. 77-115, 1979.	The relationships between the water supply and demand of the Indus River basin, one of the major river basins in the south Asian subcontinent, has not previously been established in either physical or financial terms. Although a comprehensive inventory of the basin's surface, ground and natural precipitation water is presented here, water resource development in the Indus basin has not taken place in an integrated manner and adequate data and methodologies are not available in any standard form for aggregation of total water

Subject	Source	Description
		demand in the public or private sectors. No correlation has or can then, be established with certainty between water supply and actual demand for the present, although an empirical relation is derived here based upon a number of assumptions regarding technical and socio-economic conditions. A number of policy options for water resource developments within the basin are suggested, including conservation, lining of canals, precise land levelling, inter-basin transfers, construction of off-channel storage, population redistribution, and a shift in planning to multipurpose water projects.
Evaluation process	W.A. Castagnino, "Water pollution control – some Latin American approaches", *Water pollution control in developing countries.* Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 93-101, 1978.	Reviewed is the evolution of water quality studies and control actions in Latin American countries where the setting of objectives and constraints plus the water body response to the loads are shown to be essential prerequisities. Therefore, a water quality model must be structured with pertinent parameters to find the most appropriate remedial action. Case studies of the Cauca River and Guanabara Bay in South America are presented herein. The inconvenience of adopting *a priori* standards for developing countries is stressed by showing the incidence in costs caused by high discount rates for initial investments, among other aspects. Finally, the paper analyses the problems to overcome for proper water pollution solutions in Latin America.
Evaluation process	K.J. Nath and A. Dasgupta, "Implementation of a water pollution control programme: A joint industry – government approach", *Water pollution control in developing countries.* Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 93-101, 1978.	Water pollution control on a large scale is gaining momentum in India and in other developing countries. As rapid industrial development has been rather haphazard and uncontrolled, uneven urban and industrial growth has taken place, resulting in the discharge of heavy municipal and industrial waste loads on water courses. In India, the Water Pollution Control Act was promulgated in 1974 which established effluent discharge standards, and experiments have been made with various programmes to reduce water pollution. However, the progress to date is far from satisfactory. Herein, an attempt has been made to identify the major constraints in evolving a sound water quality management programme. The authors also propose a joint industry-government approach for the management of water pollution problems in heavily industrialized urban complexes. The technical and financial aspects of the proposed plan are discussed and a definite timetable for implementation in a particular complex in West Bengal state in eastern India is suggested.
Evaluation process	R.K. Schaefer, "Economics and water conservation", *Water and Sewage Works*, vol. 126, No. 6, pp. 82-86, June 1979.	Economic analysis for water conservation is explored. Interest in water conservation has recently increased with passage of the 1972 Federal Water Pollution Control Act Amendments requiring expensive wastewater treatment. Other factors include energy crisis, climate conditions which have reduced water supplies to some heavily populated areas, rapid escalation of costs for developing water supplies including expensive treatment requirements of the Safe Drinking Water

Subject	Source	Description
		Act, and alternative water resources use conflicts. Water conservation plant must include analysis of industrial and domestic consumer use patterns together with price information, available physical and social alternatives, and innovative water supply and waste-water treatment options. Economic analysis of water conservation alternatives also requires that the cost per unit of new capacity be compared with the cost per unit of saving due to conservation. In practice, combinations of education, laws or regulations, devices such as low-flow shower heads, and pricing techniques are used to achieve water conservation. The cost-effectiveness of each must be analysed to determine a project's value. Tables listing water demand factors and costs and savings of water conserving devices are included.
General	S.D.S. Abbi, K.K. Srivastava, and A.K. Malhotra, "Estimation of water balance of Mahanadi catchment up to Hirakud dam site (1962-1966) by Thornthwaite's technique", *Indian Journal of Meteorology, Hydrology and Geophysics*, vol. 29, No. 4, pp. 717-724, October 1978.	A presentation of water balance of the Mahandi catchment up to the Hirakud dam site by Thornthwaite's method was made. For this purpose, values for the monthly water deficit, water surplus, soil moisture utilization, and soil moisture recharge for the years from 1962 to 1966 were tabulated and presented graphically.
General	E.T. Engman, "Water Resources in Agriculture: The role of soil and water in agricultural production and environmental protection", *Water for Survival*, vol. I: Proceedings of the Third World Conference on Water Resources (8 Vol), Mexico City, 23-27 April 1979. International Water Resources Association, Washington, D.C., pp. 266-275, 1979.	The Agricultural Research Service (ARS) of the United States Department of Agriculture has a unique research programme for studying water resources in agriculture. This programme is based on a modeling concept that describes the soil and water interactions in complex agricultural watersheds. Currently, research is conducted in 17 major land resource areas and includes measurements of precipitation and runoff on nearly 300 research watersheds. Most field installations include multiple nested watersheds that represent a range of area sizes and topographies. The types of studies made in these areas include routine data collection, controlled experiments of specific processes, various sampling experiments to define model parameters, and applications of remote sensing to define watershed characteristics and model parameters. Recently, with the emphasis on preserving environmental quality, many areas have also been instrumented to conduct mass balances of chemicals, such as fertilizers and pesticides. The modeling approach enables ARS to achieve its objectives with a minimum number of empirical studies. This approach may also be equally applicable to a wider range of conditions throughout the world.
Ground water	M.C. Agarwal, R. Kumar, and J. Singh, "A case study of drainage investigations at government agricultural farm, Hansi and its adjoining areas", *Water for Survival*, Volume 1: Proceedings of the Third World	Drainage investigations in a 960-hectare area were carried out with a view to assessing the existing state of, the extent and degree of drainage problems, and to identify exactly when and which areas suffer from unfavourable ground-water conditions. Detailed surveys of ground-water conditions in the area were carried out by installing 76 observation wells in a grid system,

Subject	Source	Description
	Conference on Water Resources (8 Vol), Mexico City, 23-27 April 1979. International Water Resources Association, Washington, D.C., pp. 366-393, 1979.	and ground-water table depths were recorded once each month from 1973 to 1977. Ground-water contour maps, isobath maps, and quality maps have been prepared for each month. The graphs showing ground-water table conditions for each year were included and discussed. The *in situ* hydraulic conductivity and transmissibility of soil formation have been estimated. The effect of rainfall patterns and canal water supply schedule on water table fluctuation have also been studied. On the basis of the above investigations, it may be stated that there are no serious problems of water logging in the area, and whatever little problem exists over a small area close to the irrigation canal, especially during the monsoon period, can be ameliorated by providing speedy disposal of excess rainfall by proper surface drainage or by storing rainwater in dugout ponds. The area has good subsurface natural drainage and there is no need for tile drainage.
Ground water	C.S. Rao, "The effect of water table fluctuations on water quality: A case history", *Indian Journal of Meteorology, Hydrology, and Geophysics*, vol. 29, No. 4, pp. 691-694, October 1978.	The effect of water table fluctuations on ground-water salinity was observed for three well waters near Visakhapatnam, India. The electrical resistivity of the water sample in the well is taken to represent the salinity of the water. A correlation between the electrical resistivities of ground-water samples and the corresponding water table positions over a period of 15 months was brought out. A peculiar in-phase relation between the water level hydrograph and the salinity curve was recorded, the explanation for which was given in terms of the hydrogeology of the layers constituting the "host" rock.
Ground water	R.F. Willis, "Ground-water exploration and development techniques", *Journal* of the American Water Works Association, vol. 71, No. 10, pp. 556-561, October 1979.	Many techniques are available for exploring for ground-water and for developing the source when it is located. Ground-water exploration is undertaken when the quantity and quality of the desired water is known, but not where the water is located. Ground-water development is the means by which a known ground-water source is brought into production. Many of the techniques described in this article were successfully employed by the Portland (Oregon) Water Bureau in its recent ground-water exploration and development project.
Identification of pollutants	M.A. Aziz, "New Approach for predicting dissolved oxygen levels of polluted streams", *Water pollution control in developing countries.* Proceedings of the International Conference, Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 211-217, 1978.	This paper represents an attempt to predict dissolved oxygen levels of organically polluted streams based on rates of change of major controlling parameters which have been studied in a simulated stream under varying conditions of pollution load, micro-organisms, velocity, depth of flow, and temperature. Based on these rates, a mathematical model has been developed and tested on a natural stream polluted by a single sewage effluent discharge. The model has been found successful in predicting dissolved oxygen levels at various stations downstream.
Identification of pollutants	S. Barabas, "Outline of a global water quality monitoring pro-	A United Nations-sponsored project to monitor long-term trends in water pollution of a selected number of

Subject	Source	Description
	gramme", *Water pollution control in developing countries.* Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology Bangkok, pp. 221-228, 1978.	rivers, lakes and aquifers around the world is scheduled for gradual implementation over the next three years. The purpose of monitoring is to detect any serious deterioration of the environment as a result of the introduction of man-made pollutants and to provide advance warning to mankind. The four main components in the Global Water Quality Monitoring Programme (GWQM) are: (1) Establishment of a global network of monitoring stations at appropriate sites; (2) Adoption of uniform methodologies of water sampling and analysis; (3) Application of a continuing water quality assurance programme; and (4) Development and use of a comprehensive data storage and retrieval system. This paper describes the origin, objectives, and operational features of the United Nations-sponsored programme of international significance. Discussed are: monitoring network, including operating procedures and analytical parameters; analytical quality assurance; data storage and retrieval; and validity of global monitoring.
Identification of pollutants	S.H.C. De Silva, "River, estuary, lake and reservoir quality management", *Water pollution control in developing countries.* Proceedings of the International Conference held at AIT, Bangkok, Thailand, February 1978.	Described are water quality criteria in general use; the parameters to be monitored in water quality management of rivers, estuaries, lakes and reservoirs are defined. The difficulties faced by developing countries in implementing standards better adapted to developed countries are listed. The goal of developing countries is the achievement of a higher standard of living for their populations. The pursuance of thie objective demands growth in agriculture and industry. Such growth requires the maximum utilization of a country's water resources. Recycling or reusing sources of water supply becomes imperative. Pollution control or water quality management is thus indispensable vis-a-vis the pollution explosion.
Identification of pollutants	K.F. Jalal, "Eutrophication: Current state-of-the-art and probable areas of investigation", *Water pollution control in developing countries.* Proceedings of the International Conference, held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 169-183, 1978.	Eutrophication is the process of enriching natural waters with nutrients. A number of questions in the field are still partially or completely unanswered. These are dealt with herein: (1) Critical concentration: What is the most critical nutrient and what is its critical concentration in natural waters? What are the possible sources and their relative importance? (2) Design criteria for nutrient removal: What is the maximum permissible concentration of critical nutrient and what should be the design criteria for its removal from waste water? (3) Technology of nutrient removal: What is the most effective way of removal of nutrient? It may be physical, chemical, biological or a combination. In any given situation, what is the specific means for achieving best results? This article considers sources of phosphate and their relative importance; design criteria for phosphate removal; and the technology of phosphate removal. It is believed that in developing countries, phosphate is the most critical nutrient responsible for eutrophication. The degree of removal of phosphate

Subject	Source	Description
		from any given waste-water may vary anywhere between zero and 100 per cent depending upon: (a) available dilution; (b) background concentration of phosphate in the receiving water; and (c) critical concentration of phosphate above which algal nuisance will occur.
Network design	"Computer models to predict ground water changes", *Ground Water Age*, vol. 13, No. 11, pp. 27 and 40, July 1979.	The United States Geological Survey has begun a programme to develop computer models of the overall aquifer system of six ground-water regions of the United States: the northern Great Plains region; the High Plains region; the Central Valley of California; the sandstone aquifiers of the northern Midwest, the alluvial valleys of the Southwest, and the limestone aquifers of Florida, Georgia and neighbouring states. The models will aid in identifying the natural (pre-pumping) conditions and the changes brought about by human activities. They will also help in predicting the areal effects of present and future stresses, such as increase in pumping, artificial recharge, or waste disposal.
Saline water conversion	G. Mach, "Process for desalting of water and apparatus for performing this process", United States Patent No. 4,167,480, 5 p; Official Gazette of the United States Patent Office, vol. 986, No. 2, pp. 411-412, 11 September 1979.	A process is described for desalting water by passing a stream of water to be desalted to a reverse osmosis system having a high pressure chamber which receives the stream of water to be desalted and which discharges a stream of water enriched in salt and having semi-permeable membrane means through which essentially desalted water passes from the high pressure chamber to a desalted water chamber. Prior to its passage through the semipermeable membrane means, the stream of water is passed through at least one magnetic field so that clogging of the pores of the semipermeable membrane is reduced. The arrangement can be such that magnets are applied to the outer side of the supply conduit and are applied at diametrically opposed areas of this conduit. This provides the advantage that the magnetic field is mainly crossing at a right angle the path of flow of the water to be desalted.
Sources of pollution.	MM. El-Gabaly, "Secondary salinization and sodication in Egypt: A case study", *Water Supply and Management*, vol. 3, No. 3, pp. 179-199, 1979.	The development of secondary salinization and sodication in arid Egypt involves both natural and man-made factors including soil, climate, water, and management. The present review, aiming at a better assessment of land resources affected by secondary salinization are identified as poor leveling, fallowing, cropping patterns, insufficient leaching, and formation of a plowsol layer resulting from repeated tillage at a given depth. Procedures and programmes are recommended to alleviate the problem of secondary salinization: (1) changing surface and root zone salinity; (2) establishing a salt balance within a given area; (3) creating changes in micro-relief; (4) reducing seepage from water courses and adjacent land; (5) monitoring soil productivity; and (6) monitoring changes in the salinity of irrigation canals.

Subject	*Source*	*Description*
Sources of pollution	H. LeGrand, "Monitoring changes in ground water quality", *Water Well Journal*, vol. 33, No. 6, pp. 53-56, July 1979.	Ground water of acceptable quality is commonly in contact with water of inferior quality. Simple and economic methods of determining precisely the boundary zones between contaminated and uncontaminated water are not available. As a result, much reliance is placed on monitoring wells. Planning a monitoring programme should be based on a preliminary evaluation of the hydrogeologic framework, mobility of particular contaminants, and man-made events causing movement of contaminated water. On this basis, proper location and depth of monitoring wells can be established. Tracers have limited value in determining the rate and direction of ground water and contaminant movement due to variations in hydrogeologic conditions along the path of movement. The need for monitoring will increase, but through technological improvements, monitoring can be minimized. One such improvement is a synthetic hydrogeologic model which can simulate the behaviour of the contaminated water. Such a model, by using easily obtained data, will help to assess the need for monitoring and to conduct a monitoring programme with optimum results where it is necessary.
Sources of pollution	V.P. Singh, T.H. Wickham and I.T. Corpuz, "Nitrogen movement to Laguna Lake through drainage from rice fields", *Water pollution control in developing countries*. Proceedings of the international conference, Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 141-145, 1978.	Nitrogen losses through surface drainage showed considerable variation by site, treatment and time. All treatments in both seasons lost less N (1.1 kg/ha per crop) with incorporated N than with top-dressed N (2.9 kg/ha per crop). The difference was greatest where water was supplied continuously. Treatments with incorporated N and infiltration water management had the least losses; in fact, there was a net gain of 1.8 kg/ha per crop for these treatments. Among the water management treatments, continuous flow resulted in maximum loss (5.5 kg/ha per crop), while the infiltration treatments resulted in a net gain of 1.5 kg/ha per crop.
Streamflow and runoff	A.V. Vora, "A critical study of design flood for surplusing works of major, medium and minor irrigation projects", *Water for Survival*, Volume I: Proceedings of the Third World Conference on Water Resources (8 Vol), Mexico City, 23-27 April 1979. International Water Resources Association, Washington, D.C., pp. 185-197, 1979.	A critical review of the present practice of adopting design flood for major, medium, and minor irrigation projects in Gujarat State, India, was made. By comparing observed floods with design floods, it was pointed out that the design floods have been exceeded 1.5 to 2.7 times, even in the recent past. With the present design, the average cost of head works of major projects is about 60 per cent of total project cost, while the cost for medium projects is about 76 per cent. It was also brought out that only 35 per cent of installed storage capacity is filled for 67 per cent of the time for medium projects. It was recommended that the spillways of major and medium projects be designed for 75 per cent maximum probable flood only. The remaining 25 per cent probable flood may be passed by providing a breaching section. In two cases studied, the cost of a breaching section was found to be about 3 per cent of the cost of an additional spillway. For minor irrigation projects, overdesigning the capacity and taking a calculated risk in areas of poor foundation, as against a completely safe spillway, were recommended as acceptable alternatives.

Subject	*Source*	*Description*
Techniques of planning	K.K. Chin, "A systems approach to water quality control: Sg. S. Kiri, Malaysia as a case study", *Water pollution control in developing countries.* Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 103-110, 1978.	The Sungei (river) S. Kiri in Malaysia has experienced pollution problems as a result of industrial discharges and peat field runoff. The organic substances from palm oil waste discharge completely depleted the dissolved oxygen (DO) in the upstream section during low flow conditions. The oxidation of sulphide runoff from peat fields not only depleted the DO but also lowered the pH of the water and increased its iron and sulphate contents. To clean up the river, waste discharge and surface runoff would have to be controlled. This paper outlines the problem and proposes a systems approach for its solution. The generalized reduced gradient method is used to derive optimum flows and annual least-cost abatement. The systems approach to management of the river basin must involve complete analysis of water quality models and environmental control procedures, taking into consideration various water-use patterns, water quality criteria, and waste inputs.
Techniques of planning	L. David, "River basin development for socio-economic growth: General report", *River Basin Development: Policies and Planning.* Vol. 1. Proceedings of the United Nations Interregional Seminar on River Basin and Interbasin Development, Budapest, Hungary, September 1979, pp. 25-37.	The objective of this general report is to analyse the inseparable link between socio-economic growth and river basin development considering the latter to be a sub-system of the former. To achieve this objective, the concept of comprehensive river basin development is discussed, its systems analysis is presented, and on this basis, some of the main conditions and means of reasonable implementation of river basin development are determined. The paper lists conclusions and proposals to be used as a basis for the findings and recommendations of the seminar. The purpose of river basin development is to achieve the optimum use of natural water resources on a basin-wide scale during socio-economic growth. Comprehensive river basin development which has three evolutionary periods, must be a planned complex and interdisciplinary process controlled on a systems analysis basin. The main components of river basin development systems can be divided into four groups: components of socio-economic development; socio-economic needs for river basin development; resources needed for river basin development; and engineering activities. The system can be built up on the basis of these components and their relationships.
Techniques of planning	I. Degen, "Integrated development of river basins: Overview and perspectives", *River Basin Development: Policies and Planning,* Vol. 1. Proceedings of the United Nations Interregional Seminar on River Basin and Interbasin Development, Budapest, Hungary, September 1979, pp. 3-19.	In modern times, all aspects of the multilateral relationship between socio-economic development and the natural environment are closely related to water conditions. Therefore, river basin development designed to manage water resources on a basin-wide scale has become one of the decisive factors in the evolution of socio-economic advancement. Former isolated projects of local significance have been replaced by technically, economically superior water systems developed gradually and operated in co-ordination. In order to determine the proper development option in which limited economic and natural resources can be developed to the greatest benefit, the integrated approach to river

Subject	Source	Description
		basin development is called upon, which is realized substantially by attempting to include the largest possible number of effects into the sphere of decisions related to the development objectives. The exact identification and evaluation of development objectives and effects are fundamental prerequisites. Multiobjective decision theory should be applied along with systems analysis in order to evaluate achievement; special emphasis should be placed on the social and environmental aspects of river basin development, followed by an ex-post evaluation of river basin projects and the interbasin transfer of water resources. The application of advanced decision analysis methods does not exempt the decision maker and planner from making individual or collective judgement nor from checking conclusions against experience.
Techniques of planning	P.H. Kirshen, "Water supply planning model for West Africa", *Journal of the Water Resources Planning and Management Division*, Proceedings of the American society of Civil Engineers, vol. 105, No. WR2, pp. 413-427, September 1979.	A mixed integer programming (MIP) optimization model is formulated for use in the arid, underdeveloped Sahel-Sudan region in West Africa. Its purpose is to determine either the least-cost set of sources to meet fixed demands or the sources and water uses that maximize the net benefits of water use. Since for planning purposes the model is designed to apply to the entire region and some subareas have only small-scale development options, both large- and small-scale development of a wide variety of demands and supplies are modeled. The function can be expressed either as the minimization of supply costs or as the maximization of the net benefits of water use. The major constraints are that in each planning subarea and in each season hydrologic continuity must exist, and demand must be met. The major devision variables are the capacities of supply sources, and in the net benefit maximization case the water demand quantities. MIP is used to model the possibility of different reservoirs operating at a site.
Water treatment processes	R.J. Frankel, H.F. Ludwig, and C. Tongkasame, "Case studies of agro-industrial waste-water pollution control in Thailand", *Water pollution control in developing countries.* Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 513-524, 1978.	Thailand, as a major producer of agro-industrial exports, is experiencing increasing pollution problems from the discharge of food processing waste-waters into receiving streams. Licensing of new plants is now contingent upon prior government approval of proposed water systems. Unfortunately, adoption of excessively strict standards has led to unenforceable situations. Case studies of three important agro-industries in Thailand are represented: cane sugar, pineapple canning and fish processing industries. This paper reviews typical waste water treatment design, modifications which occurred as waste generation was reduced due to process change, and renewed interest in recirculation and reuse of waste by-products.
Water treatment processes	M.C. Lo, "Microbial Treatment and utilization of nightsoil", *Water pollution control in developing countries.* Proceedings of the international conference,	This study is divided into two stages. The first stage deals with the efficiency of nightsoil treatment with photosynthetic bacteria (PSB) and chlorella. The duration of nightsoil treatment with PSB and chlorella proved to be 20 days faster than the traditional acti-

Subject	Source	Description
	Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 701-707, 1978.	vated sludge or trickling filter method, and 10 days faster than the aerobic digestion method. Furthermore, much less sludge was produced. The second stage concerns the comparison of the by-product "chlorella for chicken feed" with ordinary commercialized feed. In meat chicken it saved 14-20 per cent in cost; in layer chicken 18 per cent; in egg production 16 per cent; and in egg weight, 5 per cent more than that of average eggs.
Water treatment processes	L. Menon, "Review of selected industrial waste treatment plants in Singapore", *Water pollution control in developing countries*, Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 261-277, 1978.	To illustrate the expertise available and experience gained in this region, the paper reviews three selected industrial waste treatment plants in Singapore. Industrial waste problems, methods of treatment, operational experiences and the final effluent of the selected textile, chicken and food processing plants to meet Singapore Government legislated sewer and watercourse standards and tariff schemes are examined. Important points in the investigation, design and operation of industrial waste treatment plants are summarized. The essential first step is that the factory should be encouraged to practice good housekeeping, water-saving and process control to minimize the cost of treatment of the wastes.
Waste treatment processes	G. Ramprasad, "Case Study of existing waste-water facilities of Surat – an Indian town", *Water pollution control in developing countries*. Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 407-413, 1978.	Waste-water facilities of collection, treatment, and disposal in Surat, India were designed in 1946 and completed in 1957 for a prospective population of 300,000 in 1976. Today the total population in the municipal limits of Surat is about 600,000, and in the sewered area it is about 450,000. There are some places in the sewered area of Surat which stink, including the waste-water treatment site. There are problems of over-flowing manholes, and waterlogging during the rainy season. This paper presents compiled data on the reasons for deficiencies in existing waste-water facilities and suggests methods to improve some of them.
Waste treatment processes	W. Rybczynski, C. Polprasert and M. McGarry, "Appropriate waste treatment for tropical climates: A state-of-the-art review", *Water pollution control in developing countries*. Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 735-742, 1978.	This paper is a condensed version of part of a study that has recently been completed at the International Development Research Centre (IDRC) in Ottawa (Rybczynski and others, 1977). The aim of this project was to identify, through a review of the technical literature, the options that are available for waste treatment in tropical climates, and particularly for developing countries in those regions. This technology review has been conducted by IDRC, but it is also the first phase in a major research project of the World Bank dealing with appropriate technologies for water supply and waste disposal.
Waste treatment processes	S. Sinnappa, "Treatment studies of palm oil mill waste effluent", *Water pollution control in developing countries*. Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of	The palm oil industry in Malaysia has grown rapidly to become one of the major revenue-earners for the country. However, the waste effluent produced from palm oil processing and its discharge into receiving streams and rivers have produced considerable damage to water resources. This paper describes a system of biodegradation procedures which enabled the resultant

Subject	*Source*	*Description*
	Technology, Bangkok, pp. 525-537, 1978.	effluent to meet most requirements of the final standards proposed by the Division of the Environment. Details and results of the successful experimental studies are included.
Waste treatment processes	P.M. Sivalingam, "Bio-degradation of palm oil sludge and its waste recovery as an energy source for animals and soil amendment", *Water pollution control in developing countries.* Proceedings of the international conference, Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 337-349, 1978.	Extensive investigations on the efficiency of the currently practised biodegradational canal system method of treating palm oil mill sludge have indicated that this mode of waste treatment is quite effective in lowering the biochemical oxygen demand (BOD) load. As such, an alternative means of palm oil sludge treatment is discussed. The utilization of palm oil sludge as a soil amendment and fish feed has also been investigated. Further, the feasibility of culturing a strain of *Chlorella sp.* isolated from the irrigational biodegradational canal system in fermented palm oil sludge supernatant and original sludge as an energy source for both human and fish consumption is also discussed. Experimental results indicate that the currently practised irrigational biodegradational canal system of treating palm oil sludge is practically inefficient, in certain palm oil estates in Malaysia, and as such the polluting effect can be eliminated by the alternative fermentation processes suggested by Webb and others (1975). With proper amendments, the sludge solids can be utilized as organic soil amendments and also as feed to carps.
Waste treatment processes	K. Suwarnarat, "An immediate means of urban water pollution control in developing countries", *Water pollution in developing countries.* Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 421-433, 1978.	Rapid urbanization in developing countries has caused water pollution problems with which existing waste water treatment methods cannot adequately cope. This paper discusses the advantages and disadvantages of the on-site treatment system, and proposes its immediate application in developing countries to alleviate and combat urban water pollution.
Waste treatment processes	E.P. Taiganides, "Energy and useful by-product recovery from animal wastes", *Water pollution control in developing countries.* Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, Thailand, pp. 315-323, 1978.	Animal wastes are "resources out of place". They contain sufficient quantities of nitrogen, phosphorus, potassium and micronutrients which serve as well-balanced fertilizers for plant growth and also as soil conditioners. Plant nutrients are in readily available forms and may be recovered in soil-plant systems within three years. Animal wastes may be converted to feed components through concentration by dehydration, by fermentation as silage, and/or by fungi/yeast, and by concentration into cellular bacterial or algal protein. Animal wastes contain energy which may be recovered as gas energy by anaerobic digestion or as solid/liquid energy by pyrolysis. Their energy content can also be reclaimed when using manures as animal and/or plant feed. This paper delineates the levels of technologies and costs for the utilization of animal wastes as plant nutrients and for energy recovery.
Waste treatment processes	V.Wu, "Use of granular activated carbon for treating indus-	Treatment of organic waste materials present in industrial and municipal waste-waters has been traditionally

Subject	Source	Description
	trial waste-waters", *Water pollution control in developing countries.* Proceedings of the international conference, held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 573-588, 1978.	accomplished by combining liquid-solid separation techniques and biological processes. As an alternative, the technology of granular activated carbon adsorption has been applied to remove organic pollutants from waste-water. The reasons for the choice of activated carbon as an adsorbent are several-fold. Carbon has been demonstrated to have good sorption characteristics for most organic compounds. This paper describes the laboratory techniques and systems designs used in assessing the feasibility of granular activated carbon for a specific application. Examined also are case studies of industrial and domestic waste-water applications of activated carbon in the United States.
Waste treatment processes	B. Volesky, "Anaerobic digestion – optimization of energy source from wastes", *Water pollution control in developing countries.* Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 365-372, 1978.	Anaerobic digestion, a traditional biological process for waste disposal, is receiving new and intense attention due to its relative simplicity and its potential to produce combustible gases. The attractiveness of anaerobic digestion for treatment of high-strength wastes in developing countries is associated with the flexible scale and low demands for more sophisticated technology. The system can be used locally as an alternative source of fuel energy for cooking, heating and driving engines. The successful use of anaerobic digestion technology for purification of household and farming wastes as well as high-strength wastes originating from industrial operations is the key to efficient fuel gas mixture production which would help to alleviate the energy crisis. A description of the process is presented with an evaluation of efficiencies and operating parameters. Biochemistry, microbiology and kinetics of this complex microbial process are mentioned, leading to better understanding of its function which should result in the design of new types of reactors, enabling optimization of some key operating parameters. Future trends and areas are identified where development is required by interdisciplinary professions.
Waste treatment processes	B. Volesky and P. Tsantrizos, "Mariculture – biological treatment industry", *Water pollution control in developing countries.* Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 351-363, 1978.	Gradual growth of industry in developing countries leads to the discharge of increasing quantities of polluted or partially polluted waters. In favourable climates, the organic and inorganic content of waste-waters can be converted in marine-aquaculture systems into a needed commodity such as fish, lobster and oyster crops. A seaweed system alone is capable of nitrogen removal in an area of 60 acres with annual production of 16,300 tons net weight of seaweeds. The mariculture system can utilize local manpower and skills and simultaneously reduce the waste BOD loadings and achieve nutrient removals, enabling the exceedence of requirements for tertiary treatment contamination levels. Experimental investigations are discussed which have been carried out in several centres around the world on algal and mariculture systems. Animal feed materials recovered from algal operations and products of the controlled ecological systems are considered. Feasibility

Subject	Source	Description
		and economics of the controlled aqueous ecosystem for purification of waste-waters are briefly analysed.
Water demand	R.L. Frnka and L.R. Cheatham, "Forecasting the need for surface water use conjunctive with ground-water", Available from the National Technical Information Service, Springfield, VA 22161 as PB80-116320, September 1979.	The objective was to provide a planning model for integrating surface-water production into ground-water supply systems for the major municipalities in Mississippi. With the use of multiple regression techniques, municipal water demand was estimated to be a function of population, industry profile and climatic factors. Forecasts for water requirements were made for future years. Primary data on operation costs and capital costs were obtained from personal interviews from over 40 municipalities. Projections of those costs necessary to meet the respective demands for each municipality were made by considering the use of present ground-water systems and hypothetical surface-water systems. A comparison of costs between the two alternatives was used to determine the feasibility of integrating surface water to ground-water production. In general the reduced electric utility costs of surface systems were not adequate to counter their increased chemical and labour costs. However, in a few cases an integrated water system might be feasible if an existing surface-water source could be enhanced at a considerably lower cost.
Water demand	W.O. Maddaus and D.L. Feuerstein, "Effect of water conservation on water demands", *Journal of the Water Resources Planning and Management Division*. Proceedings of the American Society of Civil Engineers, vol. 105, No. WR2, pp. 343-351, September 1979.	A new method for predicting long-range water demands was developed to quantify the post-drought effectiveness of water conservation in the San Francisco Bay Area. The method used general relations between water use and population density and employee density that were derived for the Bay Area. Several alternative water conservation programmes were tested using the projection model and the resulting water savings ranged from 4 per cent to 16 per cent by the year 2000. The costs of water conservation were compared with those for building new water supply projects. It was concluded that water conservation was more cost-effective than other sources of water supply.
Water in plants	D. Pasternak, J. Ben Dov and M. Forti, "Irrigation of crop and ornamental plants with sea water", Ben-Gurion University of the Negev, Beersheva (Israel). Research and Development Authority, Report Number BGUN-RDA-220-79, April 1979, p. 13.	Results of preliminary experiments to determine the growth, yield and quality of fodder halophytes under sea-water irrigation and to explore proper agro-techniques for crop production with sea water are reported. The responses to continuous trickle irrigation with sea water of 38 species were observed on a coarse granite sandy soil with very low water holding capacity in a 525 m^2 plot in the seashore grounds of the Hebrew University's Marine Laboratory in Eilat, Israel. Preliminary results made over two test periods of 18 and 4 months each indicated that 26 plant species survived and 7 species grew extremely well. It is concluded that these results demonstrated that many plant species can grow well when irrigated with water containing 4.2 per cent salts and that plants such as *Atriplex nummularia* will produce reasonable dry matter yields with high protein content. An initial list of plants which may

Subject	*Source*	*Description*
		serve as a basis for gardens irrigated with sea water is compiled based upon these results.
Water quality control	S.T. Khare, "Water Quality Management", *Water pollution control in developing countries.* Proceedings of the international conference held at Bangkok, Thailand, February 1978. Asian Institute of Technology, Bangkok, pp. 37-41, 1978.	There has been an increasing awareness of environmental protection activities in developing countries, and many States are launching ambitious programmes in this field. India is one such country where work has begun on pollution control. An Act for the prevention of water pollution was passed by Maharashtra State in 1969, followed by the Government of India in 1974; now almost all States have adopted the same. In implementing the Act, many problems have to be faced. Water quality management forms an important field in water pollution control. The various aspects of water quality management are discussed herein.
Watershed protection	F.D. Whisler and others, "Agricultural management practices to effect reductions in runoff and sediment production", Available from the National Technical Information Service, Springfield, VA 22161 as PB80-116486, October 1979, p. 47.	This study reports on the soil erosion rates for three commonly occurring soil management systems on bottomland in soybean production, on the nutrient composition of runoff from these systems, on herbicide losses from these systems, on the relationship between sediment particle size and herbicide concentrations and the effect of different soil management systems on sediment particle (aggregate) sizes. A rainfall simulator was used on plots with soybean management systems of disc, chisel and plant (conventional); planting in old soybean stubble (minimum tillage); and broadcast seeding into standing wheat (double cropping). Fallow plots were used to evaluate the management systems' effectiveness. Rainfall was applied in the fall of 1977 after soybean harvesting and again in the spring of 1978 after soybean planting. Soil loss was reduced, in order of decreasing effectiveness, by double cropping, minumum tillage, conventional and fallow. From sediment nutrient chemical analysis the percentage of fines or clay increased as the amount of sediment lost by a particular management system decreased. Greatest nutrient losses were associated with the sediment phase of the runoff. Herbicide losses were greatest for the more water soluble herbicides. The herbicides appeared to be selectively adsorbed to either the large sediment particles (probably aggregates > 2 mm) or the fine particles (probably silt and clay < 0.063 mm).

كيفية الحصول على منشورات الامم المتحدة

يمكن الحصول على منشورات الامم المتحدة من المكتبات ودور التوزيع في جميع انحاء العالم . استعلم عنها من المكتبة التي تتعامل معها أو اكتب الى : الامم المتحدة ،قسم البيع في نيويورك او في جنيف .

如何购取联合国出版物

联合国出版物在全世界各地的书店和经售处均有发售。请向书店询问或写信到纽约或日内瓦的联合国销售组。

HOW TO OBTAIN UNITED NATIONS PUBLICATIONS

United Nations publications may be obtained from bookstores and distributors throughout the world. Consult your bookstore or write to: United Nations, Sales Section, New York or Geneva.

COMMENT SE PROCURER LES PUBLICATIONS DES NATIONS UNIES

Les publications des Nations Unies sont en vente dans les librairies et les agences dépositaires du monde entier. Informez-vous auprès de votre libraire ou adressez-vous à : Nations Unies, Section des ventes, New York ou Genève.

КАК ПОЛУЧИТЬ ИЗДАНИЯ ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ

Издания Организации Объединенных Наций можно купить в книжных магазинах и агентствах во всех районах мира. Наводите справки об изданиях в вашем книжном магазине или пишите по адресу: Организация Объединенных Наций, Секция по продаже изданий, Нью-Йорк или Женева.

COMO CONSEGUIR PUBLICACIONES DE LAS NACIONES UNIDAS

Las publicaciones de las Naciones Unidas están en venta en librerías y casas distribuidoras en todas partes del mundo. Consulte a su librero o diríjase a: Naciones Unidas, Sección de Ventas, Nueva York o Ginebra.

LITHO IN U.N. THAILAND